# SCIENCE PROGRESS

## IN THE TWENTIETH CENTURY

## A QUARTERLY JOURNAL OF SCIENTIFIC WORK & THOUGHT


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# INDEX TO VOL. XVII (1922—1923)

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## RECENT ADVANCES IN SCIENCE

**MATHEMATICS.** By F. PURYER WHITE, M.A., St. John's College, Cambridge.

A FURTHER account of the work of the late H. G. Zeuthen on Enumerative Geometry and on the history of mathematics, together with a list of his writings, is given by M. Noether (*Math. Ann.*, **83**, 1921, 1–23).

Adolf Hurwitz (1859–1919) devoted himself in his earlier years to the study of algebraic functions, and his paper, "Über algebraische Correspondenzen und das verallgemeinerte Correspondenzprinzip" (*Math. Ann.*, **28**, 1887, 561) remains a classic. Later he turned to continued fractions, algebraic numbers and arithmetical properties of certain transcendental functions. A full appreciation of his life and work is given by D. Hilbert (*Math. Ann.*, **83**, 1921, 161–72).

*History.*—G. A. Miller (*Isis*, **4**, 1921, 5–12) discusses the merits and defects of the various types of mathematical history, including the treatises of Montucla and Cantor, the popular works of Ball and Cajori, and the detailed reference work of Dickson on the Theory of Numbers.

D. E. Smith (*Amer. Math. Monthly*, **28**, 1921, 296–300) prints the will of Robert Recorde (*d.* 1558), the author of *The Whetstone of Witte*, and describes the one extant portrait, dated 1556.

O. Mautz (*Verhl. Basel*, **32**, 1920–21, 104–6) has a note on the tables published in 1620 by Bürgi, which are practically a set of antilogarithms.

Cantor (*Geschichte d. Math.*, t. 3, p. 368) states that Taylor's Theorem, announced in 1712 in a letter to Machin and published in 1715 in the *Methodus Incrementorum*, was anticipated by John Bernoulli in the 1694 volume of the *Acta Eruditorum*. G. A. Gibson (*Proc. Edin. Math. Soc.*, **39**, 1921, 25–33), combatting this, calls attention to the fact that Bernoulli's theorem consists only in repeated integration by parts, and that in his illustrations the series obtained are not power series. Further, Taylor's own account of his book in the *Phil. Trans.* (**29**, 1716) shows that he appreciated the importance of his theorem.

In his lectures on the integral calculus, published in 1742, but written in 1691, John Bernoulli refers to previous lectures on the differential calculus, which he would not publish as they were contained in de l'Hospital's *Analyse des infiniment petits*, 1696. Bernoulli only advanced this claim after de l'Hospital's death, and historians are divided with regard to its justice. P. Schafheitlin (*Verhl. Basel*, **32**, 1920–21, 230–35) has now discovered at Basel the MSS. of Bernoulli's earlier lectures, which agree very closely, except in matters of arrangement, with much of de l'Hospital's book.

In a review of Cajori's valuable History of Fluxions (see SCIENCE PROGRESS, January 1921, p. 486), J. M. Child (*Math. Gazette*, **11**, 1922, 26–30) expresses the opinion that Newton's definition of a fluxion is logically sound, involving the notion of a section, and that there is in it no idea of an infinitesimal. Cajori has been misled by using an English translation instead of the original Latin.

F. Cajori (*Bull. Amer. Math. Soc.*, **27**, 1921, 453–58) traces the spread of the rival Newtonian and Leibnizian notations of the Calculus. S. Wiesner (*Jahresber. d. deut. Math. Verein*, **29**, 1920, 130–35) publishes new material for the life of Johann Bolyai from the archives in Mödling and Vienna; and L. Schlesinger (*ibid.*, 28–40) prints correspondence between Weierstrass and L. Fuchs.

*Logic and the Theory of Aggregates.*—A notable new mathematical periodical, of which the first two volumes have appeared, is *Fundamental Mathematicæ*, edited in Warsaw by S. Mazurkiewicz and W. Sierpinski. It is to deal solely with the theory of aggregates and allied questions (analysis situs, mathematical logic) and contributions will be received in French, German, English, or Italian (not Polish). The second volume (1921), 256–85 contains an article by H. Lebesgue "Sur les correspondances entre les points de deux espaces."

A. Schoenflies (*Math. Ann.*, **83**, 1921, 173–200) attempts to apply the methods of Hilbert's *Grundlagen der Geometrie* to the theory of aggregates; the terms are left undefined, only their mutual relations being considered, and the axioms are divided into groups—axioms of equivalence, of order, and so on.

N. Wiener (*Proc. Lond. Math. Soc.*, **20**, 1921, 329–46) develops a categorical theory of the structure of the line in terms of bicontinuous, biunivocal transformations.

*Algebra and Analysis.*—G. A. Miller (*Bull. Amer. Math. Soc.*, **27**, 1921, 459–62) examines and criticises adversely the Group Theory reviews which have appeared in the *Jahrbuch über die Fortschritte der Mathematik.*

W. Burnside (*Proc. Camb. Phil. Soc.*, **20**, 1921, 482–84) proves a result conjectured in his *Theory of Groups*, viz. that a simply-transitive permutation group containing a regular transitive Abelian sub-group has a self-conjugate sub-group, except possibly when the operations of the Abelian sub-group are all of the same prime order.

Vahlen extended Newton's theorem, that the first $n$ sums of powers of the roots of an equation of degree $n$ form a fundamental system for symmetric functions of the roots, by showing that if any $m$ of the numbers 2, 3, . . . $n$ be chosen and the sums $s_m, s_{2m}, s_{3m} \ldots$ be set aside then the first $n$ left form a fundamental system. B. von Ludwig (*Math. Ann.*, **83**, 1921, 67–9) now shows that if $g$ be any positive integer, $n \geqq g \geqq \frac{1}{2}(n-1)$, and from the $(g+1)$ sums $s_{g+1}, s_{g+2} \ldots s_{2g+1}$ any $n-g$ be selected, then they, together with $s_1, s_2, \ldots s_g$, form a fundamental system.

C. W. Gilham (*Proc. Lond. Math. Soc.*, **20**, 1921, 326–8) extends to forms involving any number of variables the theorems that the Jacobian of a Jacobian is reducible and that the product of two Jacobians is expressible as a sum of three term products.

Lagrange's series gives only one root of the equation $x-a-uf(x) = 0$; M. Kössler (*Proc. Lond. Math. Soc.*, **20**, 1921, 365–73) obtains series for the other roots.

An equation of the $n$th degree with rational coefficients is said to be without " affect " if its Galois group with respect to the field of rational numbers is equivalent to the symmetrical group of the $n$th degree. Hilbert proved in 1892 that such equations must exist for any $n$; I. Schur (*Jahresber. d. deut. Math. Verein*, **29**, 1920, 145–50) gives examples.

L. Berzolari (*Rend. Lombardo*, **54**, 1921, 225–38) has a note on the involution determined by a binary form of the fourth order and its Hessian.

By means of orthogonal matrices, J. Radon (*Abhl. Math. Seminar Hamburg*, **1**, 1921, 1–14) determines the maximum value of $p$ for a given $n$, such that the equation $(x_1^2 + x_2^2 + \ldots + x_p^2)(y_1^2 + y_2^2 + \ldots + y_n^2) = z_1^2 + z_2^2 + \ldots z_n^2$ can be satisfied by bilinear functions $z$ of $x$ and $y$. If $n = 2^{4a+\beta} n'$ ($\beta = 0, 1, 2, 3$; $n'$ odd) then $p = 2^\beta + 8a$, in agreement with previous results of Hurwitz.

There are not many branches of pure mathematics in which the pioneers are for the most part of the Anglo-Saxon race, but one such branch is the algebra of hypercomplex numbers. Here the important names are Hamilton, Cayley, Sylvester and, more recently, the Americans Dickson and Wedderburn; the best introduction to the subject, with full bibliographical information, is the Cambridge Tract by Dickson: *Linear Algebras*. The reason for the comparative neglect of this subject on the Continent is perhaps a general conviction that it has no applications. O. Scorza has shown, however, that it is the instrument most adapted for the study of the homographies of a Riemann matrix, *i.e.* the set of periods of an Abelian function. In the first part of a long memoir (*Rend. Circ. Mat. Palermo,* **45,** 1921, 1–204), he develops the theory of such algebras, basing his account on Dickson's tract and on papers by Wedderburn and Frobenius, but adding a few novelties of his own. Unfortunately, " ragioni linguistiche " have made him invent several new names ; thus a *nilpotent* algebra is called by him *pseudonulla,* an *idempotent* element an *automodulo,* and the *identical equation* the *equazione minima.* In the second part he applies this instrument to obtain new results in the general theory of Riemann matrices. He introduces a new number characteristic of such a matrix, the *rank,* which turns out to be, in the case of a matrix connected with a curve, the maximum degree of the minimum equation of a correspondence on the curve. He also makes use of the theory of Hermitian forms, and shows that non-singular Abelian functions with positive indices of multiplicability fall into two classes, one containing only functions with an even number of variables, the other containing functions with any number of variables and being the most natural generalisation of elliptic functions with complex multiplication.

A divergent series of positive terms which continually decrease and tend to zero becomes convergent if alternate terms are given a minus sign. Generalising this, H. Rademacher (*Math. Zs.,* **11,** 1921, 276–88) investigates sequences $\epsilon_1, \epsilon_2 \ldots \epsilon_n \ldots$ which, multiplied in order into the terms of such a divergent series, make it convergent, obtaining therefrom a theorem of Hardy and Littlewood on the asymptotic value of the number of digits equal to $\lambda$ in the first $n$ of a decimal $x$ $(0 < x < 1)$.

G. Doetsch (*Math. Zs.,* **11,** 1921, 161–79) proves a number of theorems on the Cèsaro summability of series and extends the idea of the Cèsaro mean to integrable functions.

G. Sannia (*Atti Torino,* **56,** 1921, 34–40) examines series which are absolutely summable in Borel's sense.

Since Lebesgue's extension, published in 1904, of the notion of integration, it has been the object of several investigations to determine methods of arriving at the Lebesgue integral by means of the sums used in Riemann integration. Lebesgue himself gave one such method ; others are due to de Geocze and Hahn. Denjoy, with whose name is associated a more general definition of integration than Lebesgue's, also contributed ; one of his pupils, T. J. Boks of Hilversum, investigates in detail one of his methods (*Rend. Circ. Mat. Palermo,* **45** (1921), 211–64). This he calls integration (B) ; it is more general than integration (L), but a function which is " totalisable," or, as Hobson calls it, integrable (D), although less in absolute value than a function which is integrable (B), may not itself be integrable (B). M. Boks concludes with a bibliography of papers concerned with the modern notion of the integral.

Yet another extension of integration is given by H. Hake (*Math. Ann.*, **83** (1921), 119–42). He introduces "upper" and "lower" functions for a function $f(x)$, and by means of them defines integration S. A special case of this is shown to be equivalent to integration (L), and the general case applies to functions which are integrable (Di), (H) and (D).

G. Mittag-Leffler (*C.R.*, **173**, 1921, 1041–5) extends Cauchy's Theorem to uniform functions, defined for sets of points everywhere dense, and satisfying conditions less restrictive than monogeneity.

The integral of $|f(z)|^2$ taken round a circle is at least twice as great as the same integral taken along any diameter if $f(z)$ is analytic and regular over the closed circle. F. Féjer and F. Riesz (*Math. Zs.*, **11**, 1921, 305–14) show that there is no better inequality.

The monogenic function $\sum \frac{A_n}{z - a_n}$ may have some of its apparent poles $a_n$ as regular points, but they will all be true poles if the series $\sum |A_n|$ converges rapidly enough (Borel). J. Wolff (*C.R.*, **173**, 1921, 1056–8) proves by an example that simple convergence is not sufficient, and E. Borel (*ibid.*) points out the importance of this result.

The problem of the approximate representation of an arbitrary function by means of polynomials or by means of finite trigonometric sums has been treated to a considerable extent during the last twenty years. An interesting report thereon has been presented to the American Mathematical Society by Dunham Jackson (*Bull. Amer. Math. Soc.*, **27**, 1921, 415–31). The theory goes back to Tchebychef, who between 1850 and 1860 discussed the problem of determining a polynomial $P_n(x)$, of given degree $n$, to approximate to a given continuous function $f(x)$, in such a way that the maximum of the absolute value of the error,

$$Max.\ |f(x) - P_n(x)|,$$

shall be as small as possible. An account of the early work is to be found in de la Vallée Poussin : *Leçons sur l'approximation des fonctions d'une variable réelle* (1919). Later investigations have been concerned with the degree of approximation obtained, and the most important papers are by de la Vallée Poussin and S. Bernstein.

D. Jackson himself (*Trans. Amer. Math. Soc.*, **22**, 1921, 117–28, 158–66) has dealt with the method of least $m$th powers, in which the trigonometric sum of order $n$ is found, such that the integral of the $m$th power of the absolute value of $f(x) - T_n(x)$ over the period $2\pi$ has the least possible value. The sum always exists and is uniquely determined for $m > 1$, and approaches the Tchebychef sum as a limit as $m$ tends to infinity.

Allied to the foregoing is a paper by C. Jordan (*Proc. Lond. Math. Soc.*, **20**, 1921, 297–325), which, given values $y_0, y_1, \ldots y_{n-1}$ of a function for $x_0, x_1, \ldots x_{n-1}$ determines a sequence of polynomials $\phi_m(x)$, of successive degrees $1, 2, \ldots m$, such that if

$$f_m(x) = c_0 + c_1\phi_1 + \ldots + c_m\phi_m,$$

where the $c$ are independent of $m$, then $\Sigma_i[y_i - f_m(x_i)]^2$ is a minimum for all values of $m$.

E. A. Milne and S. Pollard (*Proc. Lond. Math. Soc.*, **20**, 1921, 264–88), using the methods of Lebesgue integration, discuss the maximum errors of certain integrals and sums involving functions whose value is not precisely determined.

Recent numbers of the Paris *Comptes Rendus* contain a good deal of work on integral functions; T. Varopoulos (*C.R.*, **173**, 1921, 515, 693, 963) determines functions whose addition to the argument of an integral function does not alter its order of growth; P. Fatou (*ibid.*, 571–3) investigates integral functions with two distinct multiplication theorems; and G. Valiron (*ibid.*, 1059–61) gives several properties of the roots of the equation $f(z) = Z$.

D. G. Taylor (*Proc. Edin. Math. Soc.*, **39**, 1921, 63–7) obtains expressions for the addition of a third of a period to the argument of an elliptic function; and F. Bowman (*Proc. Lond. Math. Soc.*, **20**, 1921, 251–63) for the differential coefficient of the complete third Jacobian elliptic integral with regard to the modulus, with examples of its application.

A pair of complex numbers $z_1, z_2$ can be regarded as representing a point of a four-dimensional space, and two analytical functions $w_1 = f_1(z_1, z_2)$, $w_2 = f_2(z_1, z_2)$ give a representation of a region of this space upon another region. Such a representation is not conformal, and K. Reinhardt (*Math. Ann.*, **83**, 1921, 211–55), investigating it in detail, shows that there is nothing corresponding to Riemann's theorem—*i.e.* there are certain simple 4-dimensional regions (corresponding to circles in the plane) which cannot be reversibly represented on each other.

R. Nevanlinna (*Oversigt Finska*, A. 63, 1920–21, No. 6) obtains upper limits for the coefficients of a power series which gives a conformal representation of a star-region.

W. Windau (*Math. Ann.*, **83**, 1921, 256–79) extends to self-adjoint linear differential equations of the fourth order the work of Weyl and Hilb on those of the second order.

G. Giraud (*C.R.*, **173**, 1921, 543–6) treats non-linear differential equations of the second order in $n$ variables, of the elliptic type, by a modification of Picard's method of successive approximations, and on the lines of Hadamard and Gevrey.

R. Gosse (*C.R.*, **173**, 1921, 903–5) reduces the non-linear partial differential equation $r + f(x, y, z, p, q, t) = 0$, with two invariants of the second order, to one of three integrable types ; Riquier (*ibid.*, 754–5) extends to most general systems of partial differential equations results recently obtained by him for completely integrable systems of the first order ; and G. Cerf (*ibid.*, 1053–6) advocates the use of Pfaffian systems for the transformation of partial differential equations of the third order in two variables with second order characteristics.

The integral equations which arise in the problem of the motion of a fluid past a body have only one solution of physical significance ; H. Villat (*C.R.*, **173**, 1921 , 816–18) examines the other solutions, infinite in number, by means of the Theta-Klein functions.

G. Usoni (*Rend. Palermo*, **45**, 1921, 271–83) finds solutions in finite terms of integral equations with nucleus $x - y$.

E. L. Ince (*Proc. Roy. Soc. Edin.*, **42**, 1922, 43–53) investigates the connection between linear differential equations and integral equations. The case in which the nucleus of the integral equation arises as a Green's function (with discontinuous derivates) is well known ; the author here by another method obtains nuclei with continuous derivates.

The application of the theory of limited quadratic forms in an infinite number of variables to integral equations is familiar ; there is a similar theory in functional calculus, corresponding to the quadratic forms being linear, real, symmetric, limited functional operations. P. Nalli (*Rend. Palermo*, **46**, 1922, 49–90) studies such operations.

P. Humbert (*Proc. Edin. Math. Soc.*, **39**, 1921, 21–4) investigates polynomials which are generalisations of Pincherle's, being the coefficients of powers of $t$ in the expansion of $(1-3tx+t^3)^{-\nu}$; and B. B. Baker (*ibid.*, 58–62) expresses them as sums of three hypergeometric functions of the second order.

J. Kampé de Fériet (*C.R.*, **173**, 1921, 902–3) continues his work on generalised hypergeometric functions of two variables ; and E. G. C. Poole (*Proc. Lond. Math. Soc.*, **20**, 1921, 374–88) treats of certain classes of Mathieu functions.

E. Kogbetliantz (*Rend. Palermo*, **46**, 1922, 146–64), expanding work which has appeared in the *Comptes Rendus*, examines the summation of " ultraspherical " series by the method of de la Vallée-Poussin.

Generalising a theorem of Tchebychef, T. Nagel (*Liouville*, **4,** 1921, 343–56) proves that, if $f(x)$ be any irreducible integral function of degree greater than 1, with integral coefficients, and $P_n$ be the greatest prime divisor of $f(1) . f(2) \dots f(n)$, then the limit as $n$ tends to infinity of $n(\log n)^{\epsilon}/P_n$ is zero, where $\epsilon$ is any positive number less than 1.

P. J. Heawood (*Proc. Lond. Math. Soc.*, **20,** 1921, 233–50) discusses rational approximations to incommensurable real numbers; and O. Perron (*Math. Ann.*, **83,** 1921, 77–84) improves results of Kronecker and Minkowski on the degree of approximation to $n$ real numbers by rational fractions with a common denominator.

L. E. Dickson (*Proc. Lond. Math. Soc.*, **20,** 1921, 225–32) develops an arithmetic of quaternions, taking as integral quaternions those $a + bi + cj + dk$ in which $a$, $b$, $c$, $d$ are integers; A. Hurwitz, in his *Vorlesungen über die Zahlentheorie der Quaternionen*, published just before his death, had taken as integral those in which $a$, $b$, $c$, $d$ are either integers or halves of odd integers.

On the reciprocity formula for algebraic numbers there are papers by L. J. Mordell (*Proc. Lond. Math. Soc.*, **20,** 1921, 289–96) for the quadratic field, and by L. Koschmieder (*Math. Ann.*, **83,** 1921, 280–85) for the cubic field, the latter making use of elliptic functions.

H. Hancock (*Liouville*, **4,** 1921, 327–42) obtains integral solutions of the equation $x^2 + y^2 = z^2$ in the quadratic field.

C. Siegel (*Math. Zs.*, **11,** 1921, 246–75) deals with a theorem stated by Hilbert that every number in an algebraic field (provided that neither it nor any of its conjugate numbers are negative real quantities) can be expressed as the sum of the squares of four numbers of the field.

E. Landau (*Math. Zs.*, **11,** 1921, 317–18) has a note on the uniform convergence of Dirichlet's series; and K. Vaisala (*Acta Dorpat*, A. 1, 1921) generalises them by considering series $\Sigma a_n e^{-\lambda_n s}$, where $\lambda_n = r_n e^{i\phi_n}$, and $\lim r_n = \infty$.

*Geometry.*—In a plane a rigid system can be brought from one position to another by a single rotation about a point; in three dimensions by a rotation about a line together with a translation along the line. R. A. P. Rogers (*Proc. Roy. Irish Acad.*, **36** A, 1922, 60–73) discusses the similar reduction of a displacement in Euclidean space of $n$ dimensions; this is, of course, a representation of a real, orthogonal linear transformation.

F. Severi (*Rend. Lombardo*, **54,** 1921, 243–54) sketches a method for enumerative questions concerning curves in space of any number of dimensions; the problem is first solved for a rational curve, and then the general case of genus $p$ is arrived at by finding what is the effect on the solution if the curve acquires a new double point.

The same author (*Rend. Palermo*, **46,** 1922, 105–116) gives a simplification, suggested by remarks of Schlesinger, of the algebraic proof of the existence theorem which is given in the new *Algebraische Geometrie*, p. 334. He also shows that the most general curve, of genus $p>1$, which contains at least one linear series of freedom 1 and grade $n<\frac{1}{2}p+1$, depends precisely on $3p-3-i$ moduli, $i$ being the index of specialty of the series obtained from twice the given series.

C. V. Hanumanta Rao (*Proc. Camb. Phil. Soc.*, **20,** 1921, 434–36) proves that, considering the several modes of generation of a bicircular quartic by means of circles, a varying circle of one mode makes with two fixed circles of a second mode angles with a constant sum.

D. G. Taylor (*Proc. Edin. Math. Soc.*, **39,** 1921, 2–6) shows that on a plane cubic curve three *n–ads* can be found, every pair being in *n–ple* perspective from the points of the third.

Following Cayley, Bacharach and Gergonne, L. Casteel (*C.R.*, **173,** 1921, 512–14) constructs plane cubics through nine points by linear and quadratic constructions only.

Two papers which make use of elliptic functions, and which are both extremely detailed, are by J. Thomæ (*Jahresber. d. deut. Math. Verein*, **29,** 1920, 183–236) on Cassini curves, and by A. R. Forsyth (*Q.J. Math.*, **49,** 1921, 139–85) on the developable surfaces through a couple of guiding curves in different planes.

The usual classification of collineations of space is by means of the invariant factors of Weierstrass ; K. Kommerell (*Jahresber. d. deut. Math. Verein*, **29,** 1920, 1–27) invents a new classification, by means of three invariants of the coefficients, which is not affected by displacements before applying the collineation.

E. Veneroni (*Rend. Lombardo*, **54,** 1921, 166–74) discusses congruences of conics, and L. Godeaux (*Bull. de. l'acad. roy. de Belgique*, **7,** 1921, 596–607) a linear congruence of twisted cubics.

C. Segre (*Atti Torino*, **56,** 1921, 143–57) shows that if a two-dimensional surface in space of four or more dimensions has a double infinity of plane curves, then they must be conics and the surface must either be a ruled cubic or a surface of the fourth order of Veronese in space of four or five dimensions. He similarly reduces to a few classes surfaces with a double infinity of ordinary twisted curves.

W. Burnside (*Proc. Camb. Phil. Soc.*, **20,** 1921, 437–41) has a note on convex solids in higher space, and proves, for example, that in four dimensions six spaces determine three convex polyhedra, of which two have eight vertices and the other has nine.

On a surface in ordinary space there exists in general an infinite number of conjugate sets of curves—each curve of one set being met by each curve of the other in such a way that the tangents at the intersection are conjugate. This is no longer true in higher space. E. Bompiani (*Rend. Palermo*, **46,** 1922, 91–104) defines and investigates analogous systems of curves on surfaces in $n$ dimensions.

A. Comessatti (*Rend. Palermo*, **46,** 1922, 1–48) applies the projective differential geometry of $n$ dimensions to classify irregular algebraic surfaces in ordinary space for which the geometric genus exceeds the arithmetic genus by 1 at least and obtains the relations between the Picard simple integrals of the first kind connected with such a surface.

Darboux first investigated (1, 1) point transformations between two surfaces such that the configuration formed by two corresponding points and the tangent planes thereat is invariable when the pair of points varies; if the surfaces are not parallel they are parallel respectively either to two surfaces of equal constant total curvature or to two minimal surfaces. P. Tortorici (*Rend. Palermo*, **46,** 1922, 122–45) examines in detail the latter case.

J. A. Schouten (*Math. Zs.*, **11,** 1921, 58–88) and J. A. Schouten and D. J. Struik (*Rend. Palermo*, **45,** 1921, 313; **46,** 1922, 165–84) investigate curvature relationships for $n$-dimensional manifolds.

In the Euclidean plane a circle can be defined in two ways, as the locus of points equidistant from a given plint, or as the curve of constant curvature. If we extend these definitions to curved surfaces we get two kinds of curves; B. Baule (*Math. Ann.* **83,** 1921, 286–310) investigates conditions for them to be the same, and also examines the corresponding problem in a Riemann space, of $n$ dimensions.

B. Gambier (*C.R.*, **173,** 1921, 763–6) discusses conformal correspondences between two surfaces which conserve lines of curvature and the ratio of the absolute values of the principal curvatures.

Geometry on an algebraic curve, like so many other subjects of modern mathematics, was created by Riemann. He also recognised that algebraic functions are a special case of functions which on making a circuit round given points undergo linear homogeneous substitutions, *i.e.* solutions of homogeneous linear differential equations of Fuchs' type, the so-called Riemann's Transcendentals.

The step of proceeding to geometry on the curves arising from such transcendentals has been taken by R. König (*Rend. Circ. Mat. Palermo*, **45** (1921), 284–312). He first shows how such a curve arises from a class ($K$) of the functions and the corresponding differentials; the complementary class also comes into consideration, being characteristic for the new theory. Singularities on the curve are next investigated, and it is shown the functions cannot be chosen arbitrarily, but must be linearly independent multiples of a point set (a divisor). Part 3 generalises the Riemann-Roch Theorem and the Brill-Noether Reciprocity Theorem to transcendental curves and investigates *normal* curves. Part 4 shows how the algebraic case differs from the more general one, and, in particular, how the different ways in which the genus arises have to be generalised in different ways.

Just as with the rise of Projective Geometry attention became concentrated on conics and quadrics as generalisations of the circle and the sphere, so, in recent years, other generalisations, namely, "convex regions" and "convex bodies," have come into prominence. By a "convex body" is meant a point set $A$ which is bounded and closed and such that of the two segments of a straight line determined by two points of $A$ one always belongs wholly to $A$. It is remarkable that from the mere fact of convexity many beautiful and important results can be deduced.

A useful summary, with references, of investigations down to 1916 is given in a little book by W. Blaschke of Hamburg entitled *Kreis und Kugel*; new results are, however, continually being obtained.

A. Speiser (*Vierteljahrsschrift Zürich*, **66**, 1921, 28–38) proves that a convex surface must in general have closed geodesics.

Several recent papers relate to convex bodies in $n$ dimensions. H. Kneser (*Math. Ann.*, **82**, 1921, 287–96) shows that progress may be made even if the restriction to bounded sets is omitted. J. Radon (*Math. Ann.*, **83**, 1921, 113–15) proves a theorem enunciated by E. Helly with respect to the necessary and sufficient conditions for a set of convex bodies in $n$ dimensions to have a common point.

P. Steinhagen (*Hamburg Seminar*, **1**, 1921, 15–26) establishes for the general case inequalities between the *breadth* $b$, *i.e.* the minimum distance between two parallel tangent spaces, and the radius $r$ of the largest "sphere" which can be contained in the body. He finds that, if $n$ is odd, $b \leqq 2r\sqrt{n}$, while, if $n$ is even, $b \leqq 2r \dfrac{n+1}{\sqrt{n+2}}$.

The corresponding inequalities between the *diameter* $d$, *i.e.*

the maximum distance between parallel tangent planes, and the radius $R$ of the smallest sphere which contains the body, viz. :

$$\frac{1}{2} d \leqq R \leqq \sqrt{\frac{n}{2(n+1)}} \cdot d$$

were given by Jung in 1901; H. Lebesgue (*Liouville*, **4**, 1921, 67–96) gives new proofs and also discusses " courbes orbiformes," or " curves of constant breadth." The existence of such curves, other than the circle, was first noticed by Euler in 1778 in a memoir " de curvis triangularibus." They also arise in connection with Buffon's needle problem in the theory of probability. An important result, of which Lebesgue gives a proof, is that the curve of given constant breadth which has the least area is that formed by three equal circular arcs described with their centres at the vertices of an equilateral triangle and with radius equal to a side of the triangle. (The curve with maximum area is, of course, a circle.)

G. Tiercy (*Tôhoku Math. Journal*, **18**, 1920, 90–115; **19**, 1921, 149–63) also deals with these curves and with the corresponding " surfaces of constant breadth." The latter are usually defined as convex surfaces for which every two parallel tangent planes are at the same distance apart. K. Reidemeister (*Math. Zs.*, **10**, 1921, 214–16) shows that they may equally be defined as surfaces of constant diameter, viz. such that for each point $P_1$ of the surface there is at least one point $P_m$ of the body bounded by the surface, such that $PP' \leqq PP_m = d$, where $P'$ is any point of the body and $d$ is a constant.

The same author also (*Math. Ann.*, **83**, 1921, 116–18) gives a more elementary proof than that of Blaschke of a theorem concerning the existence of double integral connected with the area of a convex surface.

J. Pál (*Math. Ann.*, **83**, 1921, 311–19) investigates the closed convex curves which can be described by the ends of a straight line of unit length moving in a plane, showing that the oval of smallest area so obtainable is an equilateral triangle of unit height.

**METEOROLOGY.** By E. V. NEWNHAM, B.Sc., Meteorological Office, London.

*On the Dynamics of Wind* (*Q.J. Met. Soc.*, vol. xlviii, No. 201, January 1922). In this valuable paper Dr. Jeffreys attempts a classification of winds from purely dynamical considerations. The practice as regards classification has usually been to select those more obvious characteristics of a wind which strike a casual observer. Thus, winds blowing from the sea to the land during the hottest part of the day are " sea-breezes "; " monsoon " winds, on the other hand, being seasonal phenomena, are placed in a different category without reference to the possibility that they may be the result of physical causes similar to those responsible for sea-breezes. Sir Napier Shaw has, however, attempted, in recent years, a more scientific classification, and the present paper may be regarded as an extension of this attempt.

Dr. Jeffreys considers from first principles the motion of air upon the rotating earth, and points out that two accelerations and three forces have to be considered.[1] The accelerations are :

(1) The acceleration due to rotation of the Earth, whereby air that has a velocity which is constant relative to the Earth has acceleration relative to a non-rotating body.

(2) Acceleration relative to the Earth's surface.

These two accelerations are balanced by the forces of gravity, hydrostatic pressure and friction.

The equations of motion under these conditions are given in Lamb's *Hydrodynamics*. After making certain simplifying assumptions which can cause only errors of too small a magnitude to matter in this enquiry, Jeffreys arrives at the following equations, which are in a form suitable for the work in hand :

$$\frac{du}{dt} - 2\,\omega\,v\cos\theta = -\frac{1}{\rho R}\frac{\delta p}{\delta\theta} + K\frac{\delta^2 u}{\delta z^2}$$

$$\frac{dv}{dt} + 2\,\omega\,u\cos\theta + 2\,\omega\,w\sin\theta = \frac{1}{\rho\varpi}\frac{\delta p}{\delta\phi} + \kappa\frac{\delta^2 v}{\delta z^2}$$

$$\frac{dw}{dt} - 2\,\omega\,v\sin\theta = -\frac{1}{\rho}\frac{\delta p}{\delta z} - g$$

where $\omega$ = the angular velocity of rotation of the earth.
$\varpi$ = the distance from the polar axis of the point vertically below any point $p$.
$z$ = the altitude of $p$.
$R$ = the radius of curvature of the level surface at the point vertically below $p$.
$\theta$ = the angle between the normal at $p$ and the polar axis.
$\phi$ = the longitude of $p$.
$u$, $v$ and $w$ are the component velocities of $p$ in the directions of $\theta$, $\phi$, and $z$ increasing.
$\rho$ = the density of the air.
$p$ = the hydrostatic pressure.
$K$ = coefficient of eddy viscosity.
$t$ is the time.

[1] The hydro-dynamics of this subject has, of course, received much attention in the past, but advances have been made in recent years in our knowledge of atmospheric friction.

The operator $\frac{d}{dt}$ is defined by

$$\frac{d}{dt} = \frac{\delta}{\delta t} + \frac{u}{R+z}\frac{\delta}{\delta\theta} + \frac{v}{\bar{\omega}}\frac{\delta}{\delta\phi} + \frac{}{\delta z}$$

and represents the part of the acceleration which is relative to the moving Earth (the "accelerational" portion).

The parts involving $\omega$ arise from the rotation of the Earth (the "rotational" portion).

These fundamental equations can be simplified in certain cases, but it should be noted that the pressure term must always be important: if this were not the case each portion of the fluid would pursue its path independently, without interference due to impact with surrounding portions. This is never the case in the air below a height of 100 kilometres.

The first stage of the classification is the division of all winds into three main classes, namely:

*Class I.*—"Eulerian" winds, where the rotational and frictional terms are small compared with the acceleration terms. The simplified equations were first found by Euler. They are:

$$\frac{du}{dt} = -\frac{\delta p}{\rho R\delta\theta}$$

$$\frac{dv}{dt} = -\frac{\delta p}{\rho\bar{\omega}\delta\phi}$$

$$0 = -\frac{1}{\rho}\frac{\delta p}{\delta z} - g.$$

In these winds each particle of air moves with accelerated velocity corresponding with the horizontal pressure-gradient, as though friction and rotation of the axis were absent.

*Class II.*—The "geostrophic" winds of Sir Napier Shaw, where the rotational terms far exceed the accelerational and frictional terms. The equations are:

$$-2\omega v\cos\theta = -\frac{1}{\rho R}\frac{\delta p}{\delta\theta}$$

$$2\omega u\cos\theta - = \frac{1}{\rho\bar{\omega}}\frac{\delta p}{\delta\theta}$$

$$0 = \frac{1}{\rho}\frac{\delta p}{\delta z} + g$$

It should be noted that $\frac{\delta p}{R\delta\theta}$ and $\frac{\delta p}{\bar{\omega}\delta\phi}$ are simply the components of the horizontal pressure gradient. The equations show that the velocity is at right angles to the pressure gradient, but the ratio between the magnitudes of these vectors is a function of the latitude.

*Class III.*—" Antitriptic " winds, where the frictional terms exceed the rotational and accelerational terms. The equations are :

$$\kappa \frac{\delta^2 u}{\delta z^2} = \frac{1}{\rho R}\frac{\delta p}{\delta \theta}$$

$$\kappa \frac{\delta^2 v}{\delta z^2} = \frac{1}{\rho \varpi}\frac{\delta p}{\delta \phi}$$

$$\frac{\delta p}{\delta z} = -g\rho$$

Here the wind is driven along by the pressure gradient, and the friction prevents a steady increase of the velocity of a particular sample of air throughout its journey, provided that journey be long enough.

The writer proceeds to consider how the various winds of the Earth may be fitted into this scheme of classification. Considerations of space permit only of a very short summary of this second portion of the paper ; it should be observed that whereas the work up to this point is mainly a recapitulation of what has been achieved by mathematical meteorologists in the past, this second section is entirely new. The conclusion is reached that in the general circulation of wind over the globe, the modified portions due to the presence of continents, together with the cyclones of temperate latitudes, belong to the geostrophic class (Class II) ; the smaller wind system of the tropical hurricane is Eulerian (Class I) ; while the land and sea breezes, mountain and valley winds, etc., are probably more or less antitriptic (Class III). Proceeding to a more detailed consideration of a continental circulation of wind, it is pointed out that to the geostrophic term must be added one or more of the remaining terms, and reasons are advanced for selecting the accelerational rather than the frictional terms. The ordinary explanation of the Asiatic monsoon as an effect of the seasonal variation of temperature over Asia appears to be substantially correct, both qualitatively and quantitatively. Land and sea breezes are considered next and shown not to be to any considerable extent either geostrophic or Eulerian, so that they must be antitriptic. A mathematical investigation of a sea-breeze is next attempted, with results that confirm the supposition that these winds are " antitriptic." A similar investigation of a valley wind leads to a similar conclusion. In both these cases an important part is played by the departure of the " lapse rate " of temperature from the adiabatic.

*Meteorological Conditions for the Formation of Rain,* by J. Bjerknes and H. Solberg—Geophys. Pub., vol. ii, No. 3

(May 1921). This paper may be regarded as the joint production of the forecast service at Bergen, supplemented by researches carried out there and in Stockholm by T. Bergeron, in 1919, and summarises the results of three years' research into the mode of rain formation in Norway.

It has been the practice at Bergen for forecasters to attempt an explanation of all rain reported at their observing stations, and this system has done much to stimulate enquiry. A scheme of classification has been adopted, which is outlined at the end of the paper, as follows :

(I) *Cyclonic Rain.*
- (*a*) "Warm-front" rain, formed by warm air pushing upwards over a retreating wedge of cold air.
- (*b*) "Cold-front" rain formed in warm air displaced by an advancing wedge of cold air.

(II) *Instability Showers.*
- (*a*) Produced by heating from warm sea surfaces.
- (*b*) By insolation over land (local showers).

(III) *Fog and Rain* (drizzle).
Slight rain formed in the lower layers of the atmosphere by cooling of air against relatively cold land or sea surfaces.

(IV) *Orographical Rain.*
Formed in air currents when ascending mountains.

Maps showing lines of flow of the surface air are freely used throughout these researches, and in the case of the large-scale maps upon which the greatest amount of detail is depicted, isobars are omitted because the number of observing stations reporting wind is far in excess of those for which reliable readings of the barometer are available. In drawing these lines of flow the peculiarities of individual stations have been allowed for to some extent. The different classes of rain are taken one at a time, beginning with the orographical type.

*Orographical Rain.*—The synoptic charts of August 7–9, 1920, furnish instructive examples of this kind of rain. On these days a W. to N.W. wind-current crossed the Norwegian mountains. Whereas the western slopes of the mountains experienced cloudy to rainy weather, on the eastern sides it was fair and dry. The greatest falls of rain occurred along a strip of country about 50 kilometres from the coast. [This occurs sufficiently often to be apparent on maps of annual rainfall.] Between the 7th and 8th rain fell at all stations north of 61°, even at those on outlying islands of low level, but farther south a strip of coast escaped altogether. It was concluded, therefore, that the rain in the north was partly orographical and partly due to showers carried along in the westerly current from the sea, observations of showers by a steamer between Norway and the Faröe confirming this conclusion. At the southern stations where the rain was presumably orographical only, 2 mm. in 24 hours was the largest amount. Again, in the succeeding 24 hours to 7 h. on the 9th, a strip of coast escaped rain, on this occasion up to latitude 62°. The purely orographical rain farther inland in this case nowhere reached 5 mm. Three years of study of such records as these have led to the conclusion that purely orographical rain never exceeds this amount in Norway, although a westerly current in which only scattered showers are falling may yield as much as 30 mm., most of which must be orographical. In this connection it should be observed that stable air-currents when forced to ascend the mountains tend to become heavier than the surrounding air at the same level; they will therefore generally move round an obstacle rather than over it. With unstable currents, however, there is more likelihood of direct ascent of the obstacle. It is for this reason no doubt that the orographical rain from unstable currents is so greatly in excess of that from stable currents. Most of the orographical rain of Norway occurs together with rain of different origin.

*Cyclonic Rain.*—To illustrate the production of cold-front rain, an example which occurred on July 24, 1918, is examined in great detail. A mass of cold air which arrived from the west gave rise to a well-developed "squall-line" with a narrow strip of continuous rain immediately behind it and in its rear scattered showers only (this type of rain has received so much attention in the earlier papers of V. and J. Bjerknes that a detailed description is unnecessary). Several observations of the temperature of the upper air are available for the region between North-Eastern France and Southern Denmark, and enable the slope of the incoming wedge of cold air to be determined as having been roughly 1 in 275. The upper surface of the cold wedge showed in some cases as a pronounced inversion of temperature and in others as a diminution of the "lapse-rate." The explanation offered of the narrowness of the "rain band" is that the winds above the boundary surface were westerly and mostly stronger than those below, consequently the warm air did not have to ascend here as it must have done in front of the squall line.

A type of rain of the cold-front variety that may be called "prefrontal" rain, due to an opposing barrier of mountains, is also discussed.

As regards warm-front rain, due to the ascent of a retreating wedge of cold air by advancing warm air, an example in January 1921 is studied in great detail, but little is added to the general conclusions arrived at in the earlier papers of

V. and J. Bjerknes with regard to rain of this kind. On the plains the rain ceased, in the case described, with the arrival of warm surface air, but a little orographical rain continued to fall on the Norwegian mountains.

The formation of cold-front and warm-front rain is similar in summer and winter, but in summer the discontinuities of temperature at the surface are often obscured by solar heating. An example drawn from August 1919 is examined and, with the help of the large-scale stream-line maps, the disturbing effects of the various mountain ranges are traced. In this particular cyclonic depression the "warm sector" was found to diminish from day to day and soon disappeared. This led to the dispersal of the whole system, as is usual under such circumstances.

*Local Showers.*—In dealing with this part of the subject the close network of stations and construction of lines of flow are seen to be essential. For the production of these summer showers not only is convergence of the air-streams necessary, but also sufficient humidity. The latter is derived from the system of sea breezes, which play a fundamental part in the process. In one of the examples given the gradual invasion of Norway by polar air of low humidity entirely stopped a period of local showers. It is very evident throughout that the differences of pressure (always slight during this type of weather) play an insignificant part in comparison with the stability and moisture-content of the air.

BIBLIOGRAPHY

Guilbert, G., Sur l'observation des nuages en prévision du temps, *Comptes Rendus*, tome 174, 1922, pp. 817–20.

Humphreys, W. J., Fogs and Clouds, *Journal Frank. Inst.*, vol. 192, 1922, pp. 217–30, 327–84.

Kohler, Hilding, Über die Tröpfchengrossen der Wolken und die Kondensation, *Met. Zeit.*, **38**, 1921, pp. 359–65.

Mohorovicic, S., Die zweiundeinhalt Jahrhundert länge Periode der Erdeben-und Klimasschwankungen, *Met. Zeit.*, **38**, 1921, pp. 373–5.

Bjerknes, J., On the Dynamics of the Circular Vortex, with Applications to the Atmosphere and Atmospheric Vortex and Wave Motions, Geophys. Pub., vol. ii, No. 4, p. 87.

**PHYSICS.** By J. Rice, M.A., University of Liverpool.

*The Problems of Atomic Structure.*—In the previous issue of Science Progress reference was made in this section to recent work by Sir Ernest Rutherford and his pupils and its relation to one of the problems of atomic structure, *viz.* the charge on the nucleus or, what comes to the same thing, the number of electrons in its "planetary" system. It appears definitely to confirm the conclusion derived from other sources of evidence as to the precise correspondence between the charges on the nuclei of the atoms in the periodic table and the first ninety-two ordinal numbers.

The situation, however, as regards the next important problem of atomic structure, *viz.* the positions of the planetary electrons, is not so satisfactory. On this point the evidence has mostly been drawn from spectroscopy and chemical *statics*, and unfortunately the results derived from these two classes of data have been rather discordant. The great advantage of the chemical data lies in the fact that they refer to a few electrons in the atom, they have a qualitative as well as a quantitative significance, and, most important of all, they give evidence on the structure with very little reference to the difficult question of atomic *dynamics* except in its statical aspect. Spectroscopic data, on the other hand, while they deal with one electron at a time, involve complicated corrections due to all the other electrons in an atom, and can only be elucidated with reference to some system of atomic dynamics. Such a system we do not possess at present except in an embryonic form ; for if there is one thing which is certain nowadays, it is that the classical dynamics of Newton, Lagrange, and Hamilton and the electro-dynamics of Maxwell are inadequate to explain the movements within the microcosmic systems we call atoms.

From the point of view of statics alone we have all the facts of chemical combination and action, *e.g.* the tetrahedal form of the carbon atom, the periodic table, and also the information concerning the structure of crystals derived by the methods of X-ray analysis. All this points to a type of structure first suggested by G. N. Lewis and worked out in greater detail by Langmuir, and strongly supports a system of atomic *statics* proposed by Parson. One of the most important facts to which this theory appeals is the numerical position in the periodic table of the *inert* gases. Thus Helium is the second, Neon tenth, Argon eighteenth, Krypton thirty-sixth, Xenon fifty-fourth, Niton (Radium Emanation) eighty-sixth. Now $2 = 2 \times 1^2$, $10 = 2 \times (1^2 + 2^2)$, $18 = 2 \times (1^2 + 2^2 + 2^2)$, $36 = 2 \times (1^2 + 2^2 + 2^2 + 3^2)$, $54 = 2 \times (1^2 + 2^2 + 2^2 + 3^2 + 3^2)$, $86 = 2 \times (1^2 + 2^2 + 2^2 + 3^2 + 3^2 + 4^2)$. Following this clue, it is suggested that the space occupied by the atom can be conceptually divided into spherical shells and each shell divided into compartments or " cells." In the first shell, which will be a spherical space immediately surrounding the relatively minute nucleus, there will be two (hemispherical) cells. The next shell (lying between two spheres) will have four times the volume of the first and will contain 8 ( $= 2 \times 2^2$) cells of the same volume as those in the first shell, these cells most probably corresponding to octants of the outer sphere. The third shell will contain 18( $= 2 \times 3^2$) cells, and the fourth 32( $= 2 \times 4^2$) cells. These cells will all be arranged symmetrically with reference to some diametrical plane; this appears to be the significance of the factor 2. The successive atomic types are then constructed by adding successive electrons to each cell, and of course adding corresponding positive unit charges or protons to the nucleus. Thus in hydrogen one of the inner cells contains an electron, in helium the two are occupied. In lithium a third electron is added to one of the eight cells in the second shell; beryllium has two of these cells occupied, boron three, carbon four, and so on until fluorine is reached with seven of them occupied and then neon with all the cells in this shell occupied by *one* electron each. We have then completed the first short period of the table. The second short period from sodium to argon corresponds to a further addition of one electron at a time still to the second shell, and the next inert gas, argon, is reached when the second *layer* of this shell is occupied completely by eight more electrons than neon. There now follow two long periods of 18 elements each in the table, and these correspond to successive occupation by electrons of first the 18 cells in the first *layer* of the third shell, and then the 18 cells in the second layer of the third shell; and when a whole layer of cells is occupied we arrive at more inert gases, krypton and xenon. Finally there is the last complete period of 32 carrying us up to niton; but only a few elements between niton and uranium corresponding to the occupation of a few cells in the second layer of the fourth shell.

The great power of this model is the really remarkable way it accounts for the properties of the elements and compounds, especially the facts of valency, which the older theories of valence were quite inadequate to deal with. (For further details consult the references at the end of this note.) But while it is possible to suggest certain principles of *statics* which account for the maintenance of electrons in equilibrium in such positions as are suggested, it is very difficult to admit that such equilibrium would be stable under the considerable disturbing influences to which every atom is subject, i.e. *if stability is to be interpreted in terms of the older dynamics*. Further, if the physical properties (especially optical) are to be adequately explained by such models, it is necessary to permit of oscillations or rotations of the molecules around the postulated equilibrium positions, and, as mentioned above, this involves a general scheme of dynamics which is so far wanting. Now, although a general scheme is still to be sought, a particular principle due to Bohr and based on the quantum hypothesis has been applied with some success to a number of individual cases of electronic orbits; but as a general rule the models postulated in these cases have been of the "ring" rather than the "shell" type suggested by Lewis and Langmuir; *i.e.* it is assumed that the electrons circulate in a number of orbits lying in one plane, or at least in a number of parallel planes, and so the electrons are by no means confined even to the limits of a region comparable in size with one of the cells of the Lewis-Langmuir theory. Now the success of a number of researches based on such ideas is sufficient to warrant the belief that there is some element of truth in the postulated models. It is true that the particular principle which is used to select the suitable orbits from the infinite number permissible on older views is quite foreign of the classical system of dynamics; but, as stated above, that cannot be regarded to-day as a fatal flaw. An interesting feature of all these models is the abandonment of the idea that the frequency of the light emitted by an atom is related to the period of vibration of an electron in it about some state of rest or steady motion, this latter period being of course determined by the electron's environment. The present idea is rather this: each electron can circulate in one of a finite number of "stationary" orbits (which are selected by Bohr's principle); while in such an orbit its motion can be deduced by the laws of classical dynamics (but other orbits infinite in number and equally valid on the older views are ruled out because they do not conform to Bohr's principle). From time to time under external influences it leaves one orbit and takes up another with a different amount of energy. The difference of energy is radiated or absorbed at a frequency determined by Planck's law—energy = $h\nu$, where $\nu$ is the frequency and $h$ is Planck's constant.

Now, whatever may be the contradictions between the models suggested by the purely chemical and static data and by the spectroscopic data, they have one quality in common—disregard of traditional principles where these seem to cramp unduly the use of scientific imagination. It is not unnatural, therefore, that there still remain distinguished physicists who, while not denying the real advances made by such methods, still seek for solutions of our difficulties along more beaten tracks. Thus during the past few years a number of papers have been published by Sir J. J. Thomson, which, while suggesting modifications of the analytical expressions for the forces between electrified particles at very close quarters, yet retain the concepts and equations of classical dynamical and electromagnetic theory. The modifications proposed in the expressions for electric and magnetic forces allow of the electrons in Thomson's model to take up positions of rest at the corners of certain well-known polyhedra, such as the tetrahedron, the cube, the rhombic dodecahedron, the cubo-octahedron, and so in the sharing of electrons between atoms and the consequent fitting together of such models we have the explanation of certain facts of crystallography. Not only so, but Thomson, moving away from the question of spectroscopic evidence for the moment, introduces very interesting computations for such humdrum physical properties as bulk-modulus, latent heat, surface tension, and compressibility. He also makes considerable appeal to the evidence supplied by his own special experimental method of investigation, *viz.* positive ray analysis. In certain particulars, notably in the high stability of an "octet" of electrons, his models resemble those of the Lewis-Langmuir theory, but decided differences arise in the treatment of the long periods. In addition to his recently published papers he has addressed the Royal Institution at various times, and gave a very interesting course of lectures on "Atoms, Molecules, and Chemistry" at University College, London, during last May.[1]

*References*

I. Langmuir, *J. Amer. Chem. Soc.*, **41**, pp. 868, 1543 (1919); **42**, p. 274 (1920).

J. J. Thomson, *Phil. Mag.*, April 1919, March 1921, April 1922.

The recently published "Series Spectra" of N. R. Campbell (Cambridge University Preess, 10*s.* 6*d.*) gives an admirable account of the development of Bohr's ideas.

An excellect report on the atomic structure problem has been prepared for the National Academy of Sciences of America by the committee of their National Research Council. It is published as *Bulletin* No. 14 of the National Research Council, and can be obtained for 75 cents from their offices in Washington, D.C.

**PHYSICAL CHEMISTRY.** By W. E. Garner, M.Sc., University College, London.

*Ionisation and Chemical Reaction.*—The electron theory of chemical valency, which is being developed so vigorously at the present time by (Sir) J. J. Thomson, Lewis, Langmuir, and with special reference to organic chemistry by Fry, Lapworth, Robinson, and many others, has directed attention to the possibility of electrical phenomena occurring during chemical change. It is well known that at high temperatures atoms readily emit electrons, and hence reactions occurring at these

[1] The writer has just learnt that Bohr, continuing some work begun by Born and Landré, has applied his own method with some success to the *dynamics* of the Lewis-Langmuir model, and published a paper in one of the German scientific journals. At the moment the paper has not come to hand, but the writer hopes to refer to it in the next issue of Science Progress.

temperatures will be accompanied by ionisation. In low temperature reactions, however, apart from the dissociation of electrolytes in solution, the evidence for the production of ions is somewhat scanty and is almost entirely confined to those reactions where surfaces are being created or destroyed, as in the experimental work of Haber and Just on the action of water, iodine, etc., on metals, where ionisation accompanies the chemical change. Pinkus and Schulthess (*J. Chim. Phys.*, 1920, **18**, 366 and 412, and *Helv. Chim. Acta*, 1921, **4**, 288) have continued their researches on the reactions between the gases, nitric oxide, chlorine and ozone, and find, even where there is no possibility of the separation of solids or liquids, that positive and negative ions are developed during the chemical reactions. They conclude that these electrical effects are exclusively the results of the reaction processes. In the case of the formation of nitrosyl chloride excess of chlorine favours ionisation, and also that in the reation between ozone and nitric oxide, which is accompanied by a mild explosion, intense ionisation is observed. These results stand in opposition to those of Trautz and Henglein (*Zeit. Anorg. Chem.*, 1920, **110**, 237), who with a somewhat different experimental arrangement found no trace of ionisation in several reactions—the formation of nitrosyl chloride, nitrosyl bromide, hydrochloric acid, etc. They suggest that the phenomena observed by Pinkus and Schulthess are produced solely by frictional electricity. O. W. Richardson (*Phil. Trans.*, 1921 [A.], 222, 1–43) has examined the emission of electrons which occurs when fine streams of the liquid alloys $NaK_2$ and NaK are allowed to fall through carbonyl chloride, chlorine, hydrogen chloride, and water vapour at low pressures. The current-potential curves resemble those found in thermionic emission. The energy given up to the electrons by the reacting molecules is only a fraction of the total heat of reaction, this energy being divided among the atoms as well as among the electrons.

*Active Hydrogen and Nitrogen.*—Venkataramaiah reports (*Nature*, 1920, **106**, 46) that active hydrogen is produced when oxygen is exploded in excess of hydrogen. Wendt and Landauer (*J.A.C.S.*, 1922, **44**, 510) find that all ionising agents are successful activators of hydrogen, with the single exception of ultraviolet light, which is but slightly absorbed by hydrogen. Active hydrogen is thus formed when the gas is passed over a platinum wire electrically heated to 800° C. This action may, however, be due to the emission of positive ions from the impurities in the wire. The greatest activity was obtained in a Siemens tube ozoniser immersed in liquid ammonia. Hysone, as the new form of hydrogen is called, is condensed at − 180° C. The spectrum of hydrogen at the temperature of liquid oxygen shows a progressive intensification of the secondary line spectrum, which is probably due to this triatomic form. Wendt disagrees with the suggestion of Baly that hysone is probably the same as the iso-hydrogen of Harkins. It is certainly not an isotope of $H_2$ since its boiling-point is at least 70° C. above that of hydrogen. Newman (*Phil. Mag.*, 1922, **43**, 455) finds that $\alpha$-rays produce active forms of hydrogen and nitrogen at moderately high pressures—300 mm. These react with many elements, particularly with the fresh surfaces of metals. The $\alpha$-rays produce atoms on collision, which probably unite with unchanged molecules to give the triatomic forms. Zenneck (*Phys. Zeit.*, 1921, **22**, 102) describes a method of producing the afterglow of active nitrogen by an electrodeless ring current.

*Photochemical Processes.*—Recent work on phosphorescence confirms the Lenard theory. On this theory, during illumination of the phosphorescent substance by the exciting light electrons are emitted from the active centres. The conductivity of the phosphor should thus increase on illumination. Godden and Pohl (*Zeit. Physik.*, 1920, **3**, 98), using a calcium-bismuth-sodium phosphorescent substance, find that the maximum conductivity is obtained when the phosphor is exposed to the light which produces the maximum excitation of the phosphorescence. On the other hand, during the interval of emission of phosphorescent light, no conductivity due to the return of the electrons was detected. An increase in conductivity was, however, noted when the excited body was exposed to infra-red light, which accelerates the return of the electrons.

The relationship between ionisation and the decomposition of organic dyes by light has been studied by Lazareff (*Zeit. Phys. Chem.*, 1921, **98**, 94). His view of the action of light in photochemical processes, is that in some of the light-sensitive molecules an electron is activated by passing to an outer Bohr orbit. This causes a virtual increase in the size of the atom or molecule, and a light-sensitive gas mixture should undergo an increase in volume when illuminated. This phenomenon was observed by Bunsen and Roscoe and more recently by Baly and Barker in the case of gaseous mixtures containing chlorine. Lazareff has shown that the bleaching of organic dyes in the presence of oxygen up to 150 atm. obeys the law

$$-\frac{dc}{dt} = a_0(1 - e^{-kc})\,(1 - e^{-k_1c_1}).$$

R. W. Wood (*Phil. Mag.*, 1922, **43**, 757) has investigated the action of light on fluorescent substances to test the theory of Perrin's that the light emitted is due to the flashes of exploding molecules. Using a very intense beam of light, he obtained from solutions of eosin, rhodamine, and fluorescein, a number of photocompounds which were coloured but non-fluorescent. Their adsorption bands had a totally different form from those of the original substances. Rhodamine, which is almost non-fluorescent at 100° C., decomposes under the action of light almost as rapidly as at ordinary temperatures. This is contrary to Perrin's theory.

Jaeger (*Trans. Chem. Soc.*, 1921, **119**, 2070), when studying the effect of light on the salts of some organic acids, noticed that neutral salts first increased the velocity of the reaction up to a maximum, but that still larger quantities of salt diminished the velocity. The reaction could be completely stopped by addition of a sufficient quantity of the salt. The greater the electrical charge on the cation the greater the effect, ferric ion being particularly effective.

*Electrical Phenomena in Heterogeneous Systems.*—In the report on the general discussion of the Physics and Chemistry of Colloids held jointly by the Faraday Society and the Physical Society of London, contributions have been made to our knowledge of the nature of the electrical charge at the interface between two phases. The complex character of this charge at a solid-water interface is pointed out by Freundlich (p. 146), who considers that it is composed of (*a*) a space charge at the solid interface, and (*b*) a diffuse electrical double layer which projects rather deeply into the liquid (after Gouy, *Journ. de Phys.*, 1910, **9**, 457). Only that portion of the charge $\zeta$ which is entirely within the liquid and is given by the Helmholtz formula is effective in electrokinetic processes, electroendosmosis, kataphoresis, and allied phenomena, whereas the Nernst potential difference $\epsilon$ comprises the total fall in potential across the interface. $\zeta$ and $\epsilon$ have been measured for a glass surface in contact with solutions of electrolytes of varying concentrations, the former by measurement of the stream potential in a glass capillary tube and the latter by the method of Haber and Klemensiewicz. $\epsilon$ is, of course, dependent only upon the activities of the ions for which the electrode is reversible, in this case $H^{\cdot}$ ions. $\zeta$ may, however, have either a positive or negative sign independent of $\epsilon$, and it approaches zero at high electrolyte concentrations. Certain physical properties are to some extent dependent on both $\epsilon$ and $\zeta$, thus the surface tension of the water-mercury interface is not always at a maximum when $\epsilon$ possesses a zero value.

Mukherjee (p. 103) has studied the neutralisation of the charge on colloidal particles which occurs on coagulation by electrolytes. His conception of the structure of the electrical double layer is somewhat similar to that of Freundlich. The electrical charge on the colloidal particle is assumed to be due to ions which are firmly fixed by chemical forces, the average distance between each ion being large compared with molecular dimensions. The process of neutralisation of these ions is the first step in coagulation. If a solution of an electrolyte is added to the colloidal solution the " fixed " ions attract those ions with an opposite charge, and the number of " fixed " ions which are neutralised at any moment is dependent upon A, the work necessary to separate an ion from the surface and the concentration of the electrolyte. It is assumed that when the kinetic energy of the oppositely changed ion of the electrolyte exceeds W, then it is no longer held by the " fixed " ions on the surface ; the fraction of the ions in the active state is given by $e^{-\frac{W}{KT}}$. By applying the theory of adsorption developed by Langmuir, the author shows that the fraction of the fixed ions which are neutralised is a function of the valency of the oppositely charged ion of the electrolyte and its mobility. For a negative surface it is derived that the order of adsorption of cations will be Th > Al > Ba > Sr > Ca > Mg > H > Cs, Rb > K > Na > Li, an order which is found experimentally for the precipitating power of cations.

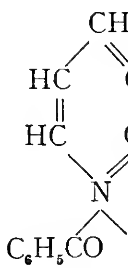
Porter (p. 135) has put forward a proof of the Helmholtz equation for the flow of liquid in electroendosmosis, which removes some of the difficulties of the Helmholtz proof and has derived a similar equation for the velocity of a colloidal particle in an electric field.

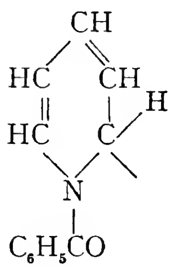
Loeb (p. 153) points out that many of the anomalies observed in the relative effects of anions on the precipitation, swelling and other properties of proteins, disappear if these properties be studied at a constant hydrogen ion concentration. The order which, according to Pauli, represents the relative efficiency of different acids on the viscosity of blood albumens is HCl > monochloracetic acid > oxalic acid > dichloracetic acid > citric acid > acetic acid > sulphuric acid > trichloracetic acid, an order which lacks any chemical character. Loeb shows that gelatine with a pH > 4·7 can only combine with cations forming metal gelatinate and at pH < 4·7 can only combine with anions forming gelatine hydrochloride, etc. Thus when a protein is placed in a solution of NaCl it will combine with Na to form sodium proteinate as soon as the pH is higher than that of the isoelectric point of the protein, and when the pH falls below this value the Na is given off and protein chloride is formed. The amount of acid required to bring isoelectric gelatine to the same pH depends only on the basicity of the acid and its degree of ionisation. The influence of acids and bases on the physical properties of proteins is quite different from that stated in the Hofmeister series of ions, if these properties be compared at the same pH. Thus the amount of swelling of gelatine at pH = 3 is almost the same for nitric, hydrochloric, trichloracetic, phosphoric, and oxalic acids. Sulphuric acid, however, gives, as is expected, one-half the effect.

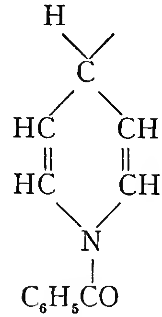
*Boundary Lubrication.*—W. B. Hardy (*Proc. Roy. Soc.*, 1921, A **100**, 550) has examined the lubricating properties of the aliphatic hydrocarbons, acids, and alcohols. In the case of volatile substances it was possible to admit the substance to the slider and plane surface in the form of vapour mixed with air, and to determine the effect of varying the concentration in the vapour state on the lubricating properties. Below certain concentrations of vapour, the amounts of adsorbed lubricant were insufficient to produce any change in the static friction between the clean surfaces of the slider and the plane surface. As the concentration in the vapour state increases above these limits, the static friction decreases down to a constant value, which is independent of further additions of lubricant even to flooding.

## ORGANIC CHEMISTRY. By O. L. Brady, D.Sc., F.I.C., University College, London.

*The Free Ammonium Radical.*—The discovery of the diaryl nitrogens has revived interest in the isolation of the ammonium radical. Schlubach and Ballauf (*Ber.*, 1921, **54**, 2811) continuing the work of the former (*Ber.*, 1920, **53**, 1689) have electrolysed solutions of tetraethylammonium iodide in liquid ammonia at −70°. A deep blue solution forms round the cathode, which solution is immediately decolorised by iodine with the formation of tetraethylammonium iodide and reacts with sulphur and with dimethyl pyrone. The blue solution gradually becomes colourless when kept at low temperatures, but still retains its reactivity. The reactive colourless solution is best obtained, however, by allowing a slight excess of tetraethylammonium chloride to react for twenty-four hours with a solution of potassium in liquid ammonia at − 70°. The authors suggest that the blue solution contains tetraethylammonium $N(C_2H_5)_4$ and the colourless reactive solution the associated compound $[N(C_2H_5)_4]_2$. Weitz, Roth and Nelken (*Ann.*, 1921, **425**, 161) by the action of zinc dust on a mixture of pyridine and benzoylchloride have isolated a brown crystalline compound which has the composition $C_{12}H_{10}ON$ to which they give the name benzoyl pyridinium and formulate as (i), though they consider that it can react as (ii) or (iii):


(i)


(ii)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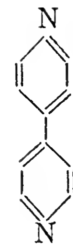
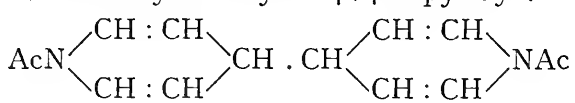
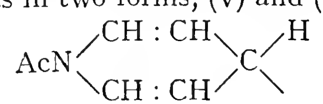

(iv)

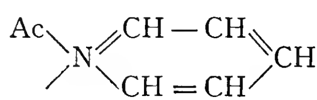
When solutions of this compound are shaken with air or treated with halogens they are decolorised, 4 : 4′-dipyridyl (iv) and benzoic acid being the principal products.

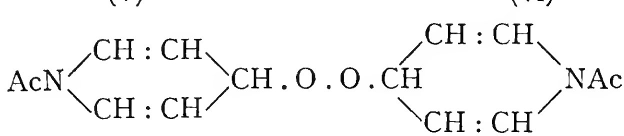
Dimroth and Heene (*Ber.*, 1921, **54**, 2934) by reducing a mixture of pyridine and acetic anhydride with zinc dust have obtained 1 : 1′-diacetyltetrahydro-4 : 4′-dipyridyl :



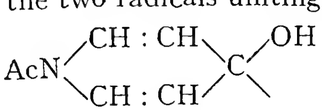
which is dissociated on gentle warming in glacial acetic acid, giving an intensely blue solution. This is decoloured by air or by iodine, the products in the former case being mainly 4 : 4′-dipyridyl with some pyridine, and in the latter the reverse. The explanation suggested for this change is similar to that proposed by Weitz, Roth and Nelken, namely, that the radical reacts in two forms, (v) and (vi) :

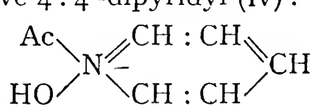

(v)


(vi)


(vii)

Reacting the first form a peroxide (vii) is formed which through the intermediate formation of a compound (viii) loses acetic acid, the two radicals uniting to give 4 : 4′-dipyridyl (iv) :

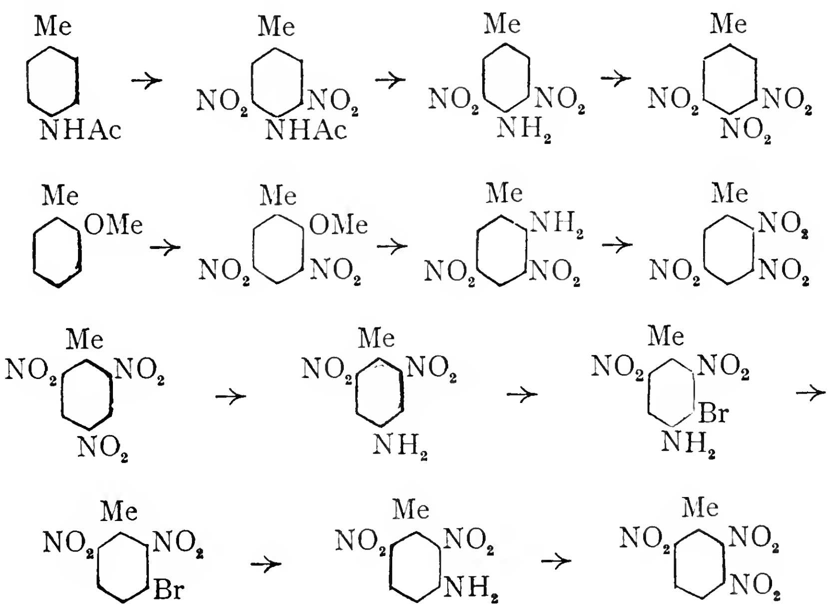

(viii)


(ix)

When the compound reacts in the second form, iodine or hydroxyl is added, giving (ix), which again loses acetic acid to give pyridine.

1 : 1′-Dibenzyltetrahydro-4 : 4′-dipyridyl has long been known, but it is only recently that Emmert (*Ber.*, 1920, **53,** 370) has shown that it undergoes dissociation in solution. Weitz and Nelken (*Ann.*, 1921, **425,** 187) have now succeeded in isolating 1-benzylpyridinium as a deep red crystalline compound dissolving in alcohol to a deep blue solution.

*The Nitration of Toluene.*—The extensive use of trinitrotoluene as a filling for high explosive shell during the war resulted in a large amount of research on the various isomeric nitro-compounds of toluene and a general study of the nitration of this body. Some of this work is now being published. The state of our knowledge in 1914 of the nitration of toluene was summarised by Will (*Ber.*, 1914, **47,** 704). At this time but three of the six possible isomeric trinitrotoluenes were known, all three being formed in the nitration of toluene. The main product of this reaction consists of 2 : 4 : 6-trinitrotoluene, the 2 : 3 : 4- and 3 : 4 : 6-trinitro-compounds totalling but approximately 4 per cent. resulting from the nitration of that amount of *m*-nitrotoluene formed in the first stage. Since that date Körner and Contardi (*Atti. R. Accad. Lincei*, 1914, [v], **23,** ii. 464 ; 1915, [v], **24, i.** 888 ; 1916, [v], **25,** ii. 339) have prepared the remaining isomerides by the following series of reactions :



Will stated that none of these compounds was formed in the nitration of toluene, but Drew (*Trans. Chem. Soc.*, 1920, **117**, 1615) found that 2 : 3 : 6-trinitrotoluene was produced to a small extent in the nitration of *m*-nitrotoluene, while Marqueyrol, Koehler and Jovinet (*Bull. Soc. Chim.*, 1920 [iv], **27**, 420) also isolated a third trinitrotoluene from the nitration products of *m*-nitrotoluene, but did not identify it.

A quantitative study of the nitration of toluene by the method of thermal analysis has now been published by Gibson, Duckham and Fairbairn (*Trans. Chem. Soc.*, 1922, **121**, 270). The mononitration of toluene, the nitration of the three nitrotoluenes to dinitrotoluenes and the nitration of the latter to trinitrotoluenes, have all been studied quantitatively and the necessary binary and ternary fusion diagrams constructed.

Under normal conditions, such as obtain in manufacture, toluene on nitration gives a mixture containing 61 to 63 per cent. of *o*-nitrotoluene, 33·5 to 32 per cent. of *p*-nitrotoluene, and 4·5 to 4·2 per cent. of *m*-nitrotoluene. Low temperature nitration reduces slightly the amount of *m*-nitrotoluene, and by nitration with nitric acid alone at 0° as little as 2·5 per cent. of this compound is formed. *o*-Nitrotoluene on dinitration gives a mixture of 66·6 parts of 2 : 4-dinitrotoluene and 33·3 parts of 2 : 6-dinitrotoluene ; *p*-nitrotoluene gives 2 : 4-dinitrotoluene only ; *m*-nitrotoluene gives a mixture of approximately 55, 25, and 20 parts of 3 : 4-, 2 : 3-, and 3 : 6-dinitrotoluenes respectively. On trinitration 2 : 4- and 2 : 6-dinitrotoluenes give 2 : 4 : 6-trinitrotoluene only ; 3 : 4-dinitrotoluene a mixture of 83 parts of 3 : 4 : 6- and 17 parts of 2 : 3 : 4-trinitrotoluenes ; 2 : 3-dinitrotoluene a mixture of 84 parts 2 : 3 : 4- and 16 parts of 2 : 3 : 6-trinitrotoluenes ; 3 : 6-dinitrotoluene a mixture of 87 parts of 3 : 4 : 6- and 13 parts of 2 : 3 : 6-trinitrotoluenes.

The nitration of toluene gives, therefore, the following products in the various stages :

| Mononitrotoluenes. | | Dinitrotoluenes. | | Trinitrotoluenes. | |
|---|---|---|---|---|---|
| ortho- . | 62 per cent. | 2 : 4- | 74·8 per cent. | 2 : 4 : 6- | 95·5 per cent. |
| para- . | 33·5 ,, ,, | 2 : 6- | 20·7 ,, ,, | 3 : 4 : 6- | 2·9 ,, ,, |
| meta- . | 4·5 ,, ,, | 3 : 4- | 2·5 ,, ,, | 2 : 3 : 4- | 1·3 ,, ,, |
| | | 2 : 3- | 1·1 ,, ,, | 2 : 3 : 6- | 0·3 ,, ,, |
| | | 3 : 6- | 0·9 ,, ,, | | |

*Electronic Conception of Organic Compounds.*—Two papers have been published (Lapworth, *Trans. Chem. Soc.*, 1922, **121**, 416 ; Kermack and Robinson, *ibid.*, 427) in which an attempt is made to correlate a few of the reactions of organic chemistry with the Thomson and Lewis-Langmuir theories of atomic structure. It is impossible to do justice to this subject in a short review, and readers must be referred to the original papers.

**BIOCHEMISTRY.** By J. C. DRUMMOND, D.Sc., F.I.C., University College, London.

*Milk.*—Few problems in biochemistry have attracted more attention recently than certain aspects of the physiological process of milk secretion, and many papers in the last year have dealt with the influence of the diet of the lactating animal on the composition and nutritive value of the milk.

The importance of a well-balanced ration adequate in vitamins to ensure the production of a milk rich in these indispensable factors has been recognised in a general way since the experiments of McCollum, Simmonds and Pitz (*J. Biol. Chem.*, 1916, **27**, 33), and McCollum and Simmonds (*Amer. J. Physiol.*, 1918, **46**, 275), but nevertheless the recent results of Dutcher, Eckles, Dahle, Mead and Schaefer (*J. Biol. Chem.*, 1920, **45**, 119) and of Hess, Unger and Supplee (*J. Biol. Chem.*, 1920, **45**, 229) are interesting. These two groups of investigators showed almost simultaneously that cows fed on rations low in the antiscorbutic factor yield a milk which is deficient in this substance.

More recently this influence of this accessory factor content of the diet on the nutritive value of the milk has been further emphasised in the case of the other two vitamins, namely A and B. Drummond, Coward and Watson (*Biochem. J.*, 1921, **15**, 540) found wide variations in the vitamin A content of milk fats and butter which appeared to be due largely to differences in the rations of the cows, an observation which has recently been confirmed for the A factor and extended to apply to the B factor by Kennedy and Dutcher in America (*J. Biol. Chem.*, 1922, **50**, 339).

The significance of these discoveries is far-reaching, for it is at once apparent that sooner or later the regulations concerning the control of the composition of milk and milk products must be reconsidered from this standpoint.

A series of papers by Hartwell raise a number of interesting problems. In a study of the influence of diet on mammary secretion in rats (*Biochem. J.*, 1921, **15**, 140) she found that, whilst an excess of carbohydrate in the diet had practically no effect on the milk supply and excess of fat relatively little, an excess of protein appears to alter the composition of the milk and after a time the milk supply ceases. Following up this observation she recorded (*Biochem. J.*, 1921, **15**, 563) a confirmation of this detrimental effect on the young of a high protein diet (40 per cent. by dried weight) for the mother during lactation. The cause of failure of the young is, in her opinion, due to an actual toxicity of the milk as well as to the failure of the milk flow. She does not regard the symptoms as being due to absence of vitamins, for she records cases in which healthy litters were raised by a mother on a diet of white bread alone. This latter observation is rather unexpected and quite contrary to the writer's experience, who has also seen many cases of failure to raise rat litters accompanied by symptoms similar to those described by Hartwell, but only when the mother is receiving a ration inadequate in the vitamin B. Apparently this possible explanation was also in Hartwell's mind, for she has since tested the effect of adding this dietary unit (vitamin B) to the mother's diet (*Biochem. J.*, 1922, **16**, 78). Actually this addition did enable the litters to be raised, although she hesitates to ascribe the general failure to vitamin deficiency. Many of her experiments, however, require repeating, and other possible causes of the death of the young should be carefully examined before the toxic effect of the protein which she emphasises is accepted on the evidence submitted.

*Testing for the Presence of Vitamins.*—A necessary forerunner of any such reconsideration of the regulations for milk control as is referred to above is, however, the discovery of more accurate methods of estimating the amount of the vitamins present in a foodstuff than are available at present. No chemical or physical methods of any approved value have yet been advanced. The yeast test for the quantitative estimation of vitamin B at first advanced by Williams (*J. Biol. Chem.*, 1919, **38**, 465) and still supported by several workers has been shown to be untrustworthy by Souza and McCollum (*J. Biol. Chem.*, 1920, **44**, 113), and by Nelson Fulmer and Cessna (*J. Biol. Chem.*, 1921, **46**, 77): the latter having demonstrated a fundamental error in the method in showing that yeast grown in pure culture can synthesise vitamin B.

The accuracy of the biological test used for the testing of foods for the vitamin A has been considerably improved by the technique described by Zilva and Muira (*Biochem. J.*, 1921, **15**, 654). The writer can vouch for the consistent results that may be obtained by closely following this technique.

The usual method of testing quantitatively for vitamin C is laborious and of doubtful accuracy, so that confirmation of the work of Bezessonoff (*Compt. rend.*, 1921, **173**, 466), who finds the antiscorbutic factor to be associated with the power to give a characteristic coloration with a modification of the Folin-Denis phenol reagent, will be hopefully awaited.

A summary of the methods employed for the testing of food products for the three vitamins was recently presented to the Society of Public Analysts by Drummond and Watson (*Analyst*, 1922, May).

*Chemotropism.*—A very interesting biochemical study of which the results may be of great practical importance is described by Harington (*Biochem. J.*, 1921, **15**, 736). He has shown that in the infection of timber with the wood-boring Mollusc *Teredo norvegica*, which only takes place during the free-swimming larval stage, the larvæ move toward the wood under a chemical attraction. An extract of wood caused a remarkable aggregation of the larvæ, and of a number of pure substances tested the only one causing the aggregation to any marked extent was malic acid. As he points out, it is scarcely possible, in view of the natural conditions which prevail in the sea, that the larvæ are actually attracted to wood. Rather would it appear that this positive chemotropism exerted by some constituent of wood enables the larvæ to recognise wood when they come in contact with it.

*Proteins and Amino-acids.*—Slowly but surely reliable information regarding the constituent molecules of the proteins is being collected. Dakin (*J. Biol. Chem.*, 1922, **50,** 403) has carefully examined the hydrolytic products of caseinogen after tryptic digestion for the presence of hydroxy-aspartic acid, described as having been found by Skraup, but without success. The synthesis and separation of two inactive forms of the hydroxy-aspartic acid described previously by Dakin (*J. Biol. Chem.*, **48,** 273) has now been supplemented by the resolution of these acids into their optically active forms (*J. Biol. Chem.*, 1922, **50,** 403).

The nitrogen distribution of the proteins of the soya bean, cotton-seed, and coconut have been examined by Friedemann (*J. Biol. Chem.*, 1922, **50,** 17), whilst Jones, Finks and Gersdorff (*J. Biol. Chem.*, 1922, **50**, 103) report the chemical study of the proteins of the adsuki bean (*Phaseolus anjularis*). From the latter two globulins were separated which show a marked difference in their sulphur and nitrogen contents and in their nitrogen distribution as determined by the method of Van Slyke.

The proteins of the muscle tissue of the rabbit, chicken, ox, horse, sheep, and pig have been subjected to an examination of their diamino-acid content by Rosedale (*Biochem. J.*, 1922, **16,** 27). On the whole the results are in agreement with the recorded analysis for mammalian muscle proteins. The slight differences to which the author draws attention are without doubt largely due to the inaccuracies of the Van Slyke method for the distribution of nitrogen in the diamino-acid fraction. Apart from this, the red meats appear to show a higher lysine content than the white meats. A very careful and valuable re-examination of the value of gelatin as a foodstuff has been made by Robison (*Biochem. J.*, 1922, **16,** 111), who has been at great pains to consider; and as far as possible correct, the sources of error associated with metabolism experiments. He made the study on himself, and during the experimental period subsisted on a vigorously controlled dietary.

From his results it would appear that the maximum saving of body nitrogen in terms of the nitrogen minimum is between 11·9 and 15·9 per cent. All his figures are considerably below those given for the pig by McCollum (*Amer. J. Physiol.*, 1911, **29**, 210), and the discrepancy cannot be explained except by assuming a difference in the metabolism of the two species.

Reference is made to the work of Grafe (1912–14) and others on the nitrogen-sparing action of simple nitrogen compounds such as ammonium salts and urea, and it is shown that the amount of nitrogen thus spared appears to be of the same order as that spared with gelatin in Robison's experiments. The suggestion is advanced that the action of gelatin may be of the same nature as that of these simpler compounds, and consist essentially in the reduction of the waste of amino-acids derived from body-protein deamination and subsequent oxidation.

*Nitrogen of Urine.*—An outcome of this work on gelatin, which necessitated the determination of the minimum nitrogen requirements, has been a contribution by Robison (*Biochem. J.*, 1922, **16**, 131) on the distribution of the nitrogenous constituents of the urine on low nitrogen diets. The results of this study are in complete agreement with the well-known work of Folin (*Amer. J. Physiol.*, 1905, **13**, 117). The values for the total nitrogen are amongst the lowest on record.

*Pituitary Gland.*—The much-debated question whether the anterior lobe of the pituitary gland supplies a growth-promoting or growth-regulating hormone still awaits a satisfactory answer. The extensive work of T. Brailsford Robertson (*J. Biol. Chem.*, 1916, **24**, 285, 397, 409; **25**, 647, etc.), who claims to have shown acceleration of growth in young mice whose diet has been supplemented with a small dose of the anterior lobe, and to have isolated from this portion of the gland the active principle which he termed tethelin, does not receive confirmation from the investigation of Drummond and Cannan (*Biochem. J.*, 1922, **16**, 53). Tethelin as prepared by the latter workers, following closely Robertson's method, is apparently a crude mixture of lipoid substances. It is without any apparent influence on the growth of young mice, nor did any appreciable changes in the rate of growth follow the administration of the fresh anterior lobe itself. Moreover, the statistical treatment of Robertson's figures from which he derives his conclusions appears to be of doubtful validity.

*Liver Lecithin.*—Levene and Simms (*J. Biol. Chem.*, 1922, **50**, 285) record a valuable addition to Levene's careful study of the lecithins. It has already been shown that the unsaturated fatty acids of the liver lecithins on hydrogenation yield stearic and arachidic acids. From this and other data regarding the iodine value and bromine addition compounds it was concluded that liver lecithin contains more than one unsaturated fatty acid and that the individual acids differ in their degree of unsaturation.

The present paper describes the identification of these acids as oleic acid, which predominates, and arachidonic acid. The isolation of the latter acid is of interest in the light of Hartley's work (*J. Physiol.*, 1908–9, **38**, 353), who found the unsaturated acids of liver fat to yield a fatty acid which was oxidised to tetrahydroxy-arachidic acid and gave on bromination a bromide probably octobromarachidic acid.

Levene and Simms think that the liver may contain several lecithins and that oleyl lecithins predominate.

**GEOLOGY.** By G. W. TYRRELL, F.G.S., A.R.C.Sc., University, Glasgow.

*Metamorphism and Metamorphic Rocks.*—Prof. V. M. Goldschmidt has described in detail the intensification of the regional metamorphism of the clay-slates of the Caledonian fold-mountain region of Southern Norway around certain masses of granite ("Die Injektionsmetamorphose im Stavanger Gebiete," *Vidensk. Skrift.* I. *Math. Nat. Kl., Kristiania,* 1920, No. 10, pp. 142). In the Stavanger district the regional rock type is a quartz-muscovite-chlorite-phyllite. The first stage of "injection-contact-metamorphism" is the formation of a garnetiferous zone, then come porphyroblastic albite-schists, and, finally, augen-schists and injection-gneisses (lit-par-lit-gneisses). Chemically the increasing metamorphism is characterised by additions of silica and soda, possibly also lime, and the subtraction of water. The new-formed albite is believed to be due to the combination of sodium-silicate solutions ("waterglass") derived from the igneous rock, with the excess alumina of the phyllite. In the change from phyllite to albite-schist there is a considerable volume increase, and it is possible that this accounts for the ptygmatic folding (Sederholm) of the injection-gneisses. The metasomatic processes in this and other kinds of metamorphism are emphasised, and a detailed classification of metasomatic alterations in schists is given.

Goldschmidt has further elaborated his views on the metasomatic processes in silicate rocks in a recent paper (*Econ. Geol.*, 1922, **17**, 105–23). He distinguishes between metasomatism with the addition of metal compounds, and with the addition of metalloids or their compounds. Under the former are included alkali-metasomatism, magnesia-metasomatism, iron-metasomatism, and nickel-metasomatism, involving the addition of salts of these respective elements; under the latter there are included fluorine-chlorine-boron-metasomatism, sulphur-metasomatism, water and carbon-dioxide metasomatism, phosphorus-metasomatism, and silica-metasomatism. He shows that the laws of mass action apply in general to metasomatism, one important result being that in order to effect replacement, the solutions must reach a definite minimum concentration for each case. This explains why metasomatic processes are common, but not as universal as the solutions themselves, since the solutions can only occasionally reach the necessary minimum concentration.

Phenomena of the same order as those described by Goldschmidt have been dealt with in a more general manner by the late Prof. J. Barrell in his paper (edited by F. F. Grout) on "The Relations of Subjacent Igneous Invasion to Regional Metamorphism" (*Amer. Journ. Sci.* (V), 1921, **1**, 1–19; 174–86; 255–67). Barrell seeks to show that regional metamorphism is due more to igneous invasion than to depth and pressure. Some regions where the rocks have indubitably been deeply buried and closely folded show very slight metamorphism; others, in positions where depth can have had only small influence, show the highest grades of recrystallisation. He considers that recrystallisation in schists and gneisses is largely due to the emanations proceeding from subjacent batholiths. The suggestion is made that there is a rhythm between igneous activity and crust movement, injection of magma, and earth movements leading to foliation especially in the softened and weakened rocks adjacent to the batholith, alternating with one another. The activity of solutions and selective crystallisation, in a word, metasomatism, in the recrystallisation of rocks, is emphasised throughout, just as it is in Goldschmidt's work. Following a similar line of thought to Barrell's, Sederholm has written an interesting discussion of the contrast in structures and mineral composition between rocks which have suffered folding of the Alpine type, and those which make up the Grundgebirge of Scandinavia, Canada, and other Archæan regions (" Faltung und Metamorphose in Grundgebirge und in Alpinen-Gebieten," *Geol. Fören. Stockholm Förh.*, bd. **41**, hft. 3, 1919, 249–56). The Alpine type is due to the action of directed pressure near the surface of the crust; while the Grundgebirge type represents the rocks which have been pressed down into depths where uniform pressure is the rule, and where they have come under the thermal influence of regional plutonic magmas.

Mr. C. E. Tilley has recently published a notable set of papers on the ancient metamorphic rocks of the Eyre Peninsula, South Australia. The granite-gneisses of this region (*Q.J.G.S.*, 1921, **77**, pt. 2, 75–134) besides the normal biotite and hornblende-bearing varieties, include pyroxene-granites of the charnockite series and a great development of garnet-gneisses. The gneissic banding is held to be a primary flow structure in a heterogeneous magma. Various interbedded amphibolites are believed to represent earlier consolidated basic igneous rocks which have become involved in the later granite-gneisses. It is shown that this South Australian Pre-Cambrian tract has a striking resemblance to the Laurentian region of North America, particularly to the Haliburton-Bancroft area of Ontario.

A further paper deals with the dolomites and calc-magnesian-silicate rocks of the Hutchison Series, the oldest sedimentary rocks of the Eyre Peninsula (*Geol. Mag.*, 1920, **57**, 449–62; 492–500). These rocks have been invaded by the above-mentioned granite-gneisses. In the dolomites residuary crystallisation alone can account for the development of the metamorphic minerals; but for certain diopside-bearing rocks it is considered that there has been an additive metamorphism superposed on to the normal residuary crystallisation, due to the influx of silica-bearing solutions from the invading granites. The graphitic schists and gneisses which also occur in the Hutchison Series are described in another memoir (*Econ. Geol.*, 1921, **16**, 184–98). They are associated with the dolomites described above, and with para-garnet-gneisses. The graphite is ascribed to a sedimentary origin, the original rocks being regarded as bituminous shales, arkoses, and sandstones, in which carbonisation of the bituminous matter and recrystallisation of the carbon to graphite have accompanied strong metamorphism. The development of graphite along joints in some cases is possibly due to reduction of oxides of carbon by hydrogen —the carbon being supplied from carbon dioxide released during the silication of the accompanying limestones.

The metamorphic rocks of the basement series of South Victoria land are described in two recent memoirs (" The Metamorphic Rocks of South Victoria Land," 5A, W. C. Smith and F. Debenham; " The Metamorphic Rocks of the McMurdo Sound Region," 5B, W. C. Smith and R. E. Priestley, " The Metamorphic Rocks of the Terra Nova Bay Region," *British Antarctic (" Terra Nova ") Expedition*, 1910, *Geology*, vol. i, No. 5, 1921, 131–66). In the McMurdo Sound region they comprise a considerable thickness of schists and crystalline limestones probably with pyroxene-granulites, and represent metamorphosed argillaceous, calcareous, and dolomitic sediments. There is also an intrusion of biotite-hornblende-gneiss, and some hornblende-schists representing altered dyke rocks. The assemblage is remarkably similar in all characters to that described by Mr. Tilley from the Eyre Peninsula of South Australia (see above).

The Terra Nova Bay region is generally similar. A porphyritic biotite-gneiss of igneous origin occurs *in situ*. The moraines yield numerous types of ortho- and para-gneisses, along with granulites and graphitic mica schists.

H. Backlund has investigated a large collection of gneisses and schists from the Taimyr region of Northern Siberia brought back by the Russian expedition of 1900–2 under Baron E. von Toll (" Petrogenetische Studien an Taimyrgesteinen," *Geol. Fören. Stockholm Förh.*, 1918, **40**, 101–203). A large granite batholith is there in contact with a very varied series of gneisses and schists, the degree of crystallisation of which is highest against the igneous rock. Backlund further describes the curious mineralogical consequences of orogenic movement in these rocks, whereby a complicated and closely set system of shearing planes has been produced. Numerous types of hornfels and mylonite are also described. The paper constitutes a notable addition to the literature of metamorphic rocks.

While most of his report (" Report on the Geology and Geography of the Northern Part of the East African Protectorate," *Colonial Repts., Miscellaneous*, No. 91, E. A. Protectorate, 1920, pp. 29) deals with the later igneous rocks, Mr. J. Parkinson has also an interesting note on the gneisses and schists of the region described. Granitic orthogneisses, hornblende gneisses and schists of polymorphic origin, and a series of quartz-schists, marbles, etc. (Turoka Series), of clearly sedimentary origin, are described. The igneous gneisses contain marbles and abnormal gneisses with epidote, garnet, hornblende, sphene, scapolite, and carbonates, which are held to be due to the partial or complete absorption of a pre-existing sedimentary series, and are similar to described examples in Mozambique and Canada.

The metamorphism of the Mona Complex of Anglesey is ascribed by Mr. E. Greenly in his recent monumental work (" The Geology of Anglesey," vols. i and ii, pp. 980, *Mem. Geol. Surv. Gt. Britain*, 1919) to the effects of superimposed foldings. There are three primary recumbent folds piled one on the other, and in each the intensity of the metamorphism decreases upwards. The metamorphism is believed to be a function of the thickness of cover present when the fold was developing, not of the subsequent cover ; so that metamorphism could develop in a higher fold without appreciably increasing the metamorphic grade of a subjacent fold. As the dynamic metamorphism could only take place at the locus of folding, the lower folds were metamorphically inert when the upper and later ones were developed above them. There is a great wealth of observation and theory concerning metamorphic rocks in Mr. Greenly's work, which it is quite impossible to summarise adequately here.

By ingenious methods of fractional extracts, elutriation, etc., Mr. A. Brammall has been enabled to make a study of the mineralogical changes that take place during the transformation of shales to slates and phyllites (*Min. Mag.*, 1920, **19,** 211–24). The impure sericitic mica in shales, rich in magnesia, lime, and iron oxides, is accompanied by an obscure chloritic substance. The change to slates and phyllites is marked by the establishment of a metastable ternary system of white mica, chlorite, and quartz ; the ferromagnesian impurities temporarily accommodated in the sericite of the shale supplying increment to the chloritic substance, which gains in size and mineralogical definition, while the mica becomes clearly muscovitic. Free silica is a by-product of this mineralogical differentiation.

*Regional and Stratigraphical Geology.*—A new book by Prof. J. W. Gregory (*The Geology and Rift Valleys of East Africa*, pp. 479, Seeley Service & Co., Ltd., 1921) deals with the fascinating tectonic problems of the Great Rift Valley system in particular, and also summarises the geology of the several parts of East Africa from Egypt to Madagascar, paying especial attention to British East Africa (Kenya Colony). The tectonic structure of the Rift Valley system and its relation to contemporary earth movements is the main theme of the book. The rifting began much earlier than is usually supposed. While the movements took place mainly from Oligocene to Recent times, there was a preparatory stage in the late Cretaceous. The formation of the rifts was accompanied by great and long-continued volcanic activity.

Holtedahl's investigation of the rocks and fossils of the Hecla Hook system in Bear Island, midway between Norway and Spitsbergen, throws much light on Lower Palæozoic palæogeography in the American-Arctic region (*Norsk Geol. Tidsskr.*, 1919, **5,** 121–48). On the basis of his own and the earlier Swedish collections he has established that two fossiliferous horizons are present in the Hecla Hook system, belonging respectively to Middle and Lower Ordovician ; and that the organisms are definitely American in character and affinities. These horizons are correlated with the Black River and Canadian-Ozarkian horizons of North America. These discoveries bring the lower part of the Hecla Hook of Bear Island into correlation with the Durness Limestone of the North of Scotland, and the Porsanger and Varanger Series of Finmarken in Northern Norway. Furthermore, the typical Hecla Hook of Spitsbergen itself, concordant in strike, lithological characters, and stratigraphical relations, with that of Bear Island, may now be regarded as of Ordovician age. A note in *Nature* (April 29, 1922, p. 561) announces that A. Hoel has now definitely established the Ordovician age of the Hecla Hook in Spitsbergen, by which is doubtless meant that the characteristic fossils have been found in these hitherto barren rocks.

In his latest work on the platinum regions of the Urals, Prof. Duparc and his collaborator, M. N. Tikonowitch, show that the source of the platinum is primarily dunite and to a less extent pyroxenite (*Le Platine et les Gîtes platinifères de l'Oural et du Monde.* Geneva, 1920, 542 pp.). The dunite is surrounded by a zone of pyroxenite, and both are enclosed in great masses of gabbro.

Mr. E. R. Stanley, the Government Geologist of New Guinea, has written a very useful summary of the geology of this great island, incorporating therein a large amount of new information (*Bull. Territory of Papua*, No. 1, 1921, 15 pp.). The rocks range from an Archæan complex of metamorphic rocks and intrusions to Late Tertiary sediments which are strongly developed in the littoral and some inland areas. The region naturally shows the connection between the Indo-Malay islands and Australasia. The trend lines of Suess's First Australian Arc pass right along the length of New Guinea, and show a connection through the Waigeo and Sula island groups with Celebes and possibly Borneo.

Other notable recent contributions to regional and stratigraphical geology are the following:

Green, J. F. N., The Geological Structure of the Lake District, *Proc. Geol. Assoc.*, 1920, **31**, 109–26.

Jehu, T. J., The Archæan and Torridonian Formations and the Later Intrusive Igneous Rocks of Iona, *Trans. Roy. Soc. Edin.*, 1922, **53**, pt. 1, 165–87.

Moon, F. W., and Sadek, H., Topography and Geology of Northern Sinai, pt. 1, Session 1919–20, *Ministry of Finance, Egypt, Petroleum Research Bull.*, No. 10, 1921, 154 pp.

Park, J., Geology and Mineral Resources of Western Southland, Bull. No. 23, *Geol. Surv. New Zealand*, 1921, 88 pp.

Ferguson, D., Geological Observations in the South Shetlands, the Palmer Archipelago, and Graham Land, Antarctica, *Trans. Roy. Soc. Edin.*, 1921, **53**, pt. 1, 29–55.

Tyrrell, G. W., A Contribution to the Petrography of the South Shetland Islands, the Palmer Archipelago, and the Danco Land Coast, Graham Land, Antarctica, *ibid.*, 57–79.

Thomas, H. H., On the Innes Wilson Collection of Rocks and Minerals from the South Shetland Islands and Trinity Island, *ibid.*, 81–9.

Wordie, J., Shackleton Antarctic Expedition, 1914–17: Geological Observations in the Weddell Sea Area, *ibid.*, 20–6.

Vaughan, T. W. *et alia*, A Geological Reconnaissance of the Dominican Republic, *Geol. Surv. Dominican Republic, Memoirs*, **1**, 1921, 268 pp.

*Volcanology.*—The Katmai volcano of Alaska, situated on the continuation of the Aleutian chain, was, in June 1912, the scene of one of the greatest and most spectacular eruptions known in history. The bulk of the material ejected in the form of pumice, glass fragments, and other material, is estimated at five cubic miles. C. N. Fenner has presented the preliminary results of a new study (*Journ. Geol.*, 1920, **28**, 569–606). The enormous number of fumaroles in the famous Valley of Ten Thousand Smokes is believed to be due to the injection of a sill in the underlying strata, and the continued evolution of volatile matter through the shattered cover. The Katmai eruption is believed to have been due to the development of an explosive condition after some interval had elapsed subsequent to the ascent of the magma from the depths. It is suggested that current theories of volcanism may have to be revised from this new standpoint.

Mr. J. W. Shipley has made chemical observation on the emanations and incrustations in the Valley of Ten Thousand Smokes (*Amer. Journ. Sci.*, 1920, **50**, 141–53). The majority of the incrustants are secondary products arising from the decomposition of the ash by the volcanic gases, but the greater part of the escaping vapours have a magmatic origin. Water vapour is the major constituent of the emanations.

S. Tsuboi presents the results of a geological study of the insular volcano of Ôshima, off the Idzu Peninsula of Japan (*Journ. Coll. Sci. Tokyo Univ.*, 1920, **43**, Art. 6, 146 pp.). Ôshima is a basaltic volcano, consisting of a somma ring and a central cone built up of alternating lava and fragmental beds. Between A.D. 684 and 1915 it has erupted sixteen times, and shows no signs of diminution of activity. The lavas are all basic, consisting of bandaite, miharaite (basaltic lava with normative quartz and bytownite), and olivine basalt, the differentiation being ascribed to the gravitative separation of crystals.

**MINERALOGY.** By ALEXANDER SCOTT, M.A., D.Sc.

THE problem of the coloration of minerals is considered in a paper by J. Jakob (*Zeit. Kryst.*, **56**, 194, 1921), who differentiates two types of coloured minerals, one in which the so-called "chromogene," or group of colouring atoms, is a prominent constituent and another in which the colouring agent is present in small quantity in the form of a finely divided foreign substance. The latter type is discussed with reference to the author's constitutional formulæ for the silicates (*Helv. Chim. Acta*, **3**, 669, 1920), and the colour of such minerals as the felspathoids explained by the presence of unsaturated valencies through which the chromogene can unite with the silicate molecule. The coloration of substances by $\alpha$ and $\beta$ rays is explained in a similar fashion, the finely divided chromogene being assumed to unite, under the influence of the rays, with the adjacent crystal molecules with the resultant formation of the colour. The author's opinion that the "Colloidal" explanation of such colours is of little value will certainly not be universally accepted.

The effect of low temperatures on the colour of minerals has been investigated by M. Bamberger and R. Grengg (*Cent. Min.*, 65, 1921). In the case of many of the substances examined, it is found that the colour, compared with that at ordinary temperature, tends to fade at $-190°$ C. This group includes not only natural minerals, but also substances coloured by the action of radium rays. Many other substances showed no change in colour. Hydrated substances behaved in various ways, some, such as chrome alum, exhibiting a pronounced change in colour, and others, such as pentahydrated copper sulphate, no change, while ferrous sulphate became turbid.

The production of a rose colour in previously colourless fluorspar by the action of ultra-violet rays is noted by C. Doelter (*Cent. Min.*, 479, 1921). In two other papers, the same author (*Koll. Zeit.*, **26**, 23, 1920; *Sitzber. Akad. Wien*, **129**, 399, 1920) describes the results of some further experiments on the coloration of crystals by means of rays from radium. The results are considered to be favourable to the theory that the coloration is due to the presence of material in a colloidal form, the colour varying according to the degree of dispersion of the latter.

The optical behaviour of certain minerals with regard to long wave infra-red radiations has been further investigated by T. Liebisch and H. Rubens (*Sitzber. Akad. Berlin*, 876, 1919, *cf.* Science Progress, **14**, 386, 1920). In another paper (*Sitzber. Akad. Berlin*, 211, 1921) the phenomena shown by Wurtzite, Zircon, Rutile, Strontianite, and Cryolite are described. The reflection-curve for wurtzite resembles that of zinc-blende, showing a maximum at 32 $\mu$. The results previously obtained for zircon are shown to have been vitiated by the presence of impurities in the material used, and corrected values derived from the use of a crystal free from inclusions are given. For the ordinary ray DE. is 10·7, and for the extraordinary ray, 10·4. In the case of rutile, the ordinary ray curve shows a minimum at 11·1, and the extraordinary ray, one at 11·7, the values of DE. being 83 and 167 respectively. The curves for strontianite resemble those for witherite and have maxima at 47 and 42, for the rays parallel and perpendicular respectively to the vertical axis, the corresponding values of DE. being 6·6 and 6·5. The curve for the ray parallel to the twin lamellæ of a crystal of cryolite showed two maxima, while the curve for the perpendicular ray had at least one, the respective values of DE. being 8·5 and 5·7. The transparency of some of the crystals to these radiations was also examined, thin plates approximately 5 mm. in thickness being used. Both zinc blende and wurtzite were highly transparent, but rutile, owing to the great amount of reflection, was only slightly so.

The thermal expansions (linear) of pyrrhotite and magnetite have been examined by P. Chevenard (*Compt. Rend.*, **172**, 320, 1921). For the former mineral, the curve showing the linear expansion increases to a maximum at 320° C., and then remains parallel to the horizontal axis, while in the case of the latter, the corresponding curve shows a maximum at 570° C., the coefficient of expansion diminishing above this temperature. Pyrrhotite is therefore assumed to have a polymorphic transformation at 320° C. and magnetite at 570° C., the high temperature form in the latter instance being less dense than the low temperature form.

The value of physical data, such as density, elasticity constants, electrical conductivity, in geological investigations is discussed by R. Ambronn (*Gluckauf*, **57**, 481, 1921 ; *Chem. Zentr.*, **3**, 286, 1921). The classification of magmatic phenomena, on the basis of physical chemical considerations, is treated by P. Niggli (*Naturwiss.*, **9**, 463, 1921). A petrographic investigation of the formation of pseudomorphs of chlorite, sericite, and quartz after felspar is described by H. Laubmann (*Neues Jahrb. Min.*, **1**, 15, 1921). A discussion, from the chemical point of view, of the origin of certain lamprophyres is given by P. J. Beger (*Zeit. Kryst.*, **56**, 417, 1922).

In a paper on the "paragenesis" of $\alpha$-quartz, A. Johnsen (*Sitzber. Bayr. Akad.*, 321, 1920) endeavours to calculate the conditions under which a particular specimen developed, on the basis of the ratio of liquid to gaseous carbon dioxide in the inclusions, used in conjunction with already known physical chemical data. The use of quartz as a "geological thermometer" is discussed by G. Mügge (*Cent. Min.*, 609, 641, 1921).

The conditions under which fluid inclusions are formed in minerals is discussed by R. Nacken (*Cent. Min.*, 35, 1921). The basis of the discussion is the temperature-pressure diagrams of the system water-carbon dioxide, but the author concludes that in general no satisfactory determination of the pressure of formation can be made, although in the case of some water inclusions it is possible to fix the temperature of formation of the host crystal within narrow limits.

From an investigation of the properties of chalcedony and black flint, E. W. Washburn and L. Navias (*Proc. Nat. Acad. Sci.*, **8**, 1, 1922) conclude that both these minerals are essentially composed of quartz. This deduction is verified by a study of the inversion temperatures and the X-ray spectra.

In a paper on the changes in constitution which occur when clay is transformed into shales, slates and phyllites, A. Brammall (*Miner. Mag.*, **19**, 211, 1921) carries to a further stage the work done by Hutchings thirty years ago. By means of a series of analyses, the recrystallisation of the rock material as sericite, chlorite and quartz is traced and the development of the accessory minerals, such as titanite, is accounted for on the basis of the oxides set free during these changes. The origin and course of crystallisation of certain schists from Macedonia is discussed by O. H. Erdmannsdoerffer (*Zeit. Kryst.*, **56**, 419, 1921).

The investigation of Japanese kaolinite by means of heating and cooling curves is described by S. Satoh (*Journ. Amer. Cer. Soc.*, **4**, 182, 1921). Several changes, both exo- and endothermic in character, have been noted, in addition to those previously described. A differential method of examination was used, but as the supposed inert substance adopted was quartz, the results are vitiated by the changes which occur in the latter during heating and cooling.

I. Bellucci and L. Grassi (*Gazz. chim. Ital.*, **49**, 232, 1920) have described crystals of fluorapatite containing over 5 per cent. of rare earth oxides, mainly cerium. The occurrence of the scandium mineral, thortveitite, in Madagascar is noted by A. Lacroix (*Compt. Rend.*, **171**, 421, 1920). In the magnesite deposit at Galgenberge in Silesia, L. Mahlen (*Zeit. prakt. Geol.*, **28**, 155, 1920) ascribes the formation of the mineral to the leaching of magnesia from serpentine, followed by enrichment through colloidal solutions at considerable depths and ultimately by crystallisation. The amount of serpentine diminishes as the depth increases.

The metasomatic formation of breunnerite from peridotite through the agency of post-volcanic emanations such as carbon dioxide and water, is described by W. Hammer (*Cent. Min.*, 385, 1921).

R. Scharizer (*Zeit. Kryst.*, **56**, 353, 1921) continues his work on the constitution and origin of the natural sulphates of iron. In this paper the mineral *rhomboclase*, $Fe(OH)\,(H\,SO_4)_2 3H_2O$, is considered and details are given concerning its crystallographic properties and behaviour on hydrolysis. The corresponding anhydrous salt has also been prepared and the conditions of its formation examined.

The natural hydrates of ferric oxides are classified by K. Willmann (*Cent. Min.*, 673, 1921) into two groups, colloidal and crystalline hydrates. The former are regarded as forming a continuous series, the water content varying from 5 to 25 per cent. In the latter, three definite minerals are recognised, two of these being polymorphic modifications of the monohydrate $Fe_2O_3 \cdot H_2O$. The third, for which the name *limonite* is appropriated, is the substance $2Fe_2O_3 \cdot 2H_2O$. It may be noted that E. Posnjak and H. E. Merwin (*Amer. Journ. Sci.*, (4), **47**, 311, 1919) concluded that the only crystalline forms were the two types of the monohydrate. The occurrence, in a metasomatic iron ore, of an iron silica gel rich in manganese is described by F. Katzer (*Cent. Min.*, 738, 1921), while the formation of iron oölites is discussed by K. Hummel (*Metall Erz*, **18**, 577, 1921).

The technique of the micro-examination of opaque crystals is treated by M. François and C. Lormand (*Bull. Soc. chim. Fr.*, (4), **29**, 356, 1921 ; *cf.* M. François, *Compt. Rend.*, **172**, 967, 1506, 1921).

Three papers on the gypsum deposits of the English Midlands may be noted. B. Smith (*Quartz. Journ. Geol. Soc.*, **74**, 174, 1919) discusses the mode of origin of the brecciated gypsum of Chellaston and concludes that the mineral originated in its present form, and is not derived from anhydrite ; the local occurrences of the latter are likewise primary, evidence of any transformation of the one mineral to the other being practically absent. The fibrous gypsum associated with the breccia is supposed to have been deposited in open fissures, the mineral being of secondary origin. This view is not adopted by W. A. Richardson (*Miner. Mag.*, **19**, 77, 1920), who also criticises an explanation based on that advanced by S. Taber (*Trans. Amer. Inst. Min. Eng.*, **57**, 62, 1918 ; *Journ. Geol.*, **26**, 56, 1918) in the case of veins of asbestos and similar minerals. According to the latter, the force exerted by the growing crystals is sufficiently great to thrust apart the walls so that the crystals tend to make room for themselves. The former author regards the existence of forces of sufficient magnitude as very doubtful, and suggests that the gypsum veins are produced during the dehydration of the original sediments. Cracks are supposed to be formed during the contraction of a colloidal mass, and in these cracks the gypsum is contemporaneously deposited from solutions which are possibly transformed to the labile condition by release of pressure. In view of the comparatively rapid variation in the solubility of calcium sulphate as the temperature changes and the fact that the influence of pressure on the solubility of salts in water is extremely small, this explanation of the precipitation of the gypsum does not seem very satisfactory.

In a further paper the same author (*Miner. Mag.*, **19**, 196, 1921), on the basis of micro-examination of rock-gypsum, comes to the conclusion that the deposition of the material found in Nottinghamshire was mainly sedimentary, except in the case of the nodular varieties, which are regarded as concretionary in origin. Secondary changes due to the local formation of anhydrite are also described.

The origin of the so-called "glassy meteorites" or tektites is considered by V. Goldschmidt (*Zeit. Kryst.*, **56**, 420, 1920). The view of E. Suess (*Mitt. geol. Ges. Wien*, **7**, 51, 1914; H. S. Summers, *Proc. Roy. Soc. Victoria*, **21**, 423, 1909) that such objects as moldavite, billitonite, and australite have had a meteoric origin is adopted and their conditions of formation are considered. The two latter types are supposed to have been in a molten condition with low viscosity, as they possess the typical structure of "drops," the billitonites, however, being assumed to have been formed at a greater height above the earth on account of their greater size and deeper surface erosion. The tendency of moldavites to split off in spherical shells and the occurrence, in them, of elongated fluid inclusions is held to indicate a high degree of viscosity in the molten state.

The meteoric origin of the tektites is also maintained by C. E. Tilley (*Miner. Mag.*, **19**, 275, 1922) on the basis of an investigation of the densities and refractive indices of natural glasses. By plotting the specific refractivity of the glasses against the density, it is shown that the points representing the properties of the tektites lie in a field which is distinct from those of the rhyolitic and trachytic obsidians. The fields of the latter lie at the albite end of the Ab-An curve, while the field appropriate to the basalt glasses lies at the anorthite end of the same curve and in the same region as the series $MgSiO_3 - CaSiO_3$ (*cf.* E. S. Larsen, *Amer. Journ. Sci.*, **28**, 263, 1909).

**BOTANY.** By E. J. Salisbury, D.Sc., F.L.S., University College, London.

*Plant Diseases.*—F. Mensil (*Ann. d. Sci. Nat.*, Dec.) gives an excellent summary of our present knowledge of the occurrence of organisms allied to the *Trypanosomes* in plants. *Leptomonas Davidi* was first recorded by Lafont in 1909 as occurring in the latex of herbaceous species of *Euphorbia*, chiefly *E. pilulifera*, which when badly infected become markedly etiolated and eventually wither.

Artificial inoculation has been successfully accomplished, but in nature infection is brought about by Hemiptera of the genus *Stenocephalus*.

An allied Trypanosome has been found to occur in the latex of some Asclepiadaceous plants, and Franchini has recently described a similar organism in a member of the Apocynaceæ. The presence of these organisms in plants is probably more or less accidental, but that they should find in the latex a suitable environment is none the less interesting.

Brown (*Ann. Bot.*, Jan.) finds that water retained on the surface of leaves increases in conductivity, and that the higher percentage of contained salts thus indicated is capable of exerting a favourable influence on the germination capacity of the spores of *Botrytis*.

The formation of dendroid appendages on the thallus of a lichen as a response to infection by a species of *Nostoc* is described by Moreau (*Ann. d. Sci. Nat.*) in an extensive paper on the anatomy of the thallus of Stictaceous lichens. The development of these structures is accompanied by the death of the causal alga and results in a profound modification of the thallus as a whole. The facts are all the more striking in view of the presence of *Nostocs* as the normal algal constituent of the thallus of some members of the group.

*Taxonomy.*—In the current number of the *Linnean Journal*, Compton describes three new species of Coniferæ from New Caledonia, the most interesting of which is placed in a new genus *Austrotaxus*. In the female cone this closely resembles the yew, but the male fructifications differ from those of the other Taxeæ in their spike-like form. This tree, *A. spicata*, which is the southernmost representative of the group, is a large one, 15–25 metres high, occurring in forest between 1,000 and 3,000 ft. The wood consists of pitted tracheids devoid of spiral thickenings. A second monotypic genus closely allied to *Callitris* is created under the name *Callitropsis*. *C. araucarioides* is a monœcious tree some 10 metres high with stiff imbricate leaves in alternating whorls of four members. The female cone bears eight ovuliferous scales and about eight ovules, whilst the embryo is dicotyledonous.

New Pteridophyta from the same region include single species belonging to *Cyathea*, *Lindsaya*, *Asplenium*, *Elaphoglossum*, and *Gleichenia* and one *Lycopodium*.

In the December number of the *Ann. d. Sci. Nat.*, Hickel and Camus give an account of the Indo-Chinese species of *Quercus* and *Pasania*. Of the former, five species are cited belonging to the section *Euquercus* and eighteen to the section *Cyclobalanopsis*. Of these latter, nine are new species. Of the genus *Pasania*, forty-seven species are enumerated of which no less than twenty-seven are described as new.

The *Euphorbias* of Africa are the subject of a monograph by M. Denis, of which the first part appears in the January number of the *Revue Gén. de Botanique*. Three new species are added.

Brief diagnoses with some figures of ten new species of peltate-leaved *Peperomias* are furnished by Trelease in the March number of the *Bot. Gaz.*

Hybrids of *Orchis purpurella* form the subject of a paper by T. and T. A. Stephenson in the *Journal of Botany* for February.

In the same journal for March, W. E. Nicholson records the liverwort *Southbya nigrella* as a British plant from Portland.

*Ecology*.—Adamson in a lengthy paper in the *Journ. of Ecology* (vol. ix, No. 2) deals with the woodlands of Ditcham Park in Hampshire, an area with a rainfall of about 40 in. In the Beechwoods the soil varies in depth from very shallow to nearly 16 in. on the western slopes, where also the humus is deeper. The rooting depths of the ground flora are mostly 4–5 in. or 5–9 in. on the western slopes. The soil reaction mostly lies between p.H. 7·5 and p.H. 8·5, the higher values being associated with the *Mercurialis perennis*, *Sanicala europæa*, etc., whilst the lower alkalinity is met with where *Scilla nutans* is associated with the Dog's Mercury.

The flora of the five areas studied shows an aggregate of 28 trees and shrubs of which *Fraxinus excelsior*, *Acer compestre*, *Cornus sanguinea*, *Euonymus europæus*, *Sambucus nigra*, and *Sorbus aria* are the most frequent. Birch is absent, whilst Oak is very rare. 93 vascular plants and 52 Bryophytes comprise the ground flora. Large areas are more or less bare, but the chief species are *Sanicala europæa*, *Mercurialis perennis*, *Viola sylvestris*, *Ajuga reptans*, and *Euphorbia amygdaloides*.

The light intensity varies from 17·5–63 per cent. during the light phase and from 0·98–5·22 per cent. during the shade phase.

The humidity during the periods of observation was between 53 and 100 per cent. Calcicolous coppice occupying areas of felled Beechwood is characterised by an absence of any humus layer, and of course a large number of species (trees and shrubs, 33 ground flora, 136 vascular plants, and 39 Bryophytes).

The development of a Cornus scrub on a felled area is described, and after six years 73 species were found, which increased the following year to 96 and after 13 years to 90 spp.

The Oak Hazel woods exhibit a ground flora in which *Mercurialis perennis*, *Circæa lutetiana*, and *Teucrium scorodonia* are the most important members. The woods of this type furnished 32 woody species, 209 herbaceous species, and 43 Bryophytes.

Salisbury in the same journal treats of the stratification of the soil with especial reference to the hydrogen ion concentration in woodlands. Graphs of typical examples from a large mass of data are furnished showing the marked decrease in acidity that is often exhibited as one passes from the surface downwards. This is an outcome of progressive leaching and the gradual accumulation of humus in the surface layers and on the surface of undisturbed soils.

The view is advanced that this tendency results in an edaphic succession, and that woodlands, and perhaps all natural plant communities, tend to pass from a basic to an increasingly acid condition with resultant changes in their flora. This may explain not only the depression of the upper woodland limit in this country, but also some of the plant successions observed in peat.

Exceptions to the normal gradient occur where the subsoil is rich in bases and the manurial action of the leaves, etc., enriches the topmost layer. In general, buffer action is greatest at the surface where there is the greatest stability of reaction. With the same species and on the same type of soil there appears to be a fairly close relation between the organic content of the soil and the real acidity.

This stratification is reflected in the vertical distribution of the micro-organic population of the soil and in the character of the vegetation as a whole.

Atkins (*Proc. Roy. Dublin Soc.*, xvi), in a paper dealing with soil acidity, gives data respecting the reaction in various types of vegetation. Thus a sand dune with *Salsola kali* gave p.H. 8·4. An older grassy phase gave 7·2–7·8. Soil with *Ulex europæus* gave a range of 5·4–8·6 in 27 localities. *Silene maritima* 6·0–7·8 (7 loci), *Rubus fruticosus* 5·4–8·4 (17 loci), *Pteris aquilina* 5·0–7·6 (10), *Erica cinerea* 4·6–6·0 (6), *Calluna vulgaris* 4·6–5·8 (6), *Digitalis purpurea* 5·4–7·2 (2).

The effect on the growth of various tree seedlings of three types of soil, namely sand, sand + humus, pure humus with and without addition of lime, has been studied by Barrington Moore (*Ecology*, Sept.). The species used were *Pinus rigida*, *P. Banksiana*, *P. resinosa*, and *Thuja occidentalis*. As might be expected from its nitrogen content, growth was greatest on the humus soil and least in the pure sand, but the important result of the experiment was that even light liming had a detrimental effect on all the species mentioned.

The vegetation of S.E. Missouri is briefly described by Uphof in the *Amer. Journ. Bot.* The annual rainfall is high, 1·1–1·5 in., whilst the climate is characterised by hot summers (max. over 40° C.) and mild winters (min. – 5° C.).

The forests consist chiefly of Oak, of which several species are important. On the drier and less fertile soils, *Q. marilandica* is predominant. Herbs with storage organs, *e.g. Podophyllum peltatum*, are a feature of the ground flora.

The more fertile soils with higher water content bear woods of *Q. alba* and *Q. rubra*, with numerous associated trees and a shrub layer also rich in species as in individuals. The moister parts of these woods are the especial home of *Impatiens fulva*, now so abundant an alien by canals in this country.

Limestone outcrops are marked by pure stands of *Juniperus* *virginiana*, whilst swamp woods are dominated by *Taxodium distichum* and *Nyssa aquatica*.

The swamps themselves show a zonation parallel to the water margin of which the zone characterised by *Isoetes Engelmani* occurs at a depth of about 7 metres. This as the water becomes shallower is followed in turn by zones dominated respectively by Potamogetons *Elodea canadensis*, etc.; *Nuphar* and *Nymphæa*; *Scirpus lacustris*, *Typha*, *Phragmites*, *Acorus*, etc.; a very mixed assemblage of amphibious herbs, in which *Hibiscus*, *Sium*, etc., are characteristic. The floating vegetation consists largely of Lemnaceæ and *Riccia natans*.

Fritch has carried out some interesting experiments on the moisture relations of terrestrial algæ (*Ann. Bot.*, Dec.), from which it appears that they do not contain large vacuoles and, even when air-dried, retain an appreciable proportion of moisture, from 8–9 per cent., some of which probably represents retained cell sap.

The contraction on drying does not result in separation of the protoplast from the cell wall to nearly the same extent as in non-terrestrial species, so that when filaments are again moistened, the water is readily absorbed by the living contents. Compared with aquatic algæ, the contraction of the terrestrial alga appears to be much less.

**PLANT PHYSIOLOGY.** By Prof. Walter Stiles, M.A., Sc.D., University College, Reading (Plant Physiology Committee).

*Irritability and Movement in Plants.*—A considerable mass of data dealing with the reaction of plants to stimuli has accumulated since this subject was last reviewed in these pages. The contributions, as usual, come mostly, but by no means exclusively, from the Continent of Europe, and practically all the chief stimuli are included in the investigations.

The stimulus of contact has been investigated by P. Stark ("Das Resultantengesetz beim Haptotropism," *Jahrb. f. wiss. Bot.*, **58**, 475–524, 1919). Working with various varieties of oat, and also with barley and *Agrostemma githago*, he investigated the effect of stimulating the stem by stroking it in more than one place at the same horizontal level. If the stem is stimulated in this way in two places and the intensity of stimulation in the two places is equal, the stem takes up a position in a plane bisecting the angle between the vertical planes containing the two places at which the stroking is applied. As this angle increases the response is less provided the intensity of the stimulus remains the same. This result follows the parallelogram law of the resultant of forces which had previously been shown to hold in the case of phototaxis by Buder. The law also holds when the stem is stimulated in three or four different places at once.

That twining plants were sensitive to contact, in some cases at least, had been shown by Löffler as long ago as 1913. The same author has now extended his researches to a large number of species belonging to different genera ("Experimentelle Untersuchungen über Regeneration des Gipfels und Kontaktempfindlichkeit bei Windepflanzen," *Ber. deut. bot. Ges.*, **37,** 6–24, 1919).

Reaction to the gravitational stimulus has been a favourite subject of investigation. Miss T. L. Prankerd, a firm upholder of the statolith hypothesis, has discovered a tissue in the haulm of wheat composed of cells containing a single crystal of calcium oxalate. ("Statocytes of the Wheat Haulm," *Bot. Gaz.*, **70,** 148–152, 1920.) This, it is thought, may be a statolith for geo-perception, the organ being very sensitive to gravity when the haulm is laid horizontal. The rate of fall of the crystals when the tissue is inverted is 10 $\mu$ a minute, a much higher rate than that found for falling starch grains, a fact which may be correlated with the sensitivity of the organ.

The same author has recently published an account of the irritability of fern fronds, reaction to gravity being specially investigated ("On the Irritability of the Fronds of *Asplenium bulbiferum*, with Special Reference to Graviperception," *Proc. Roy. Soc.*, B, **93,** 143–152, 1922). It is shown that the life-history of the frond of *Asplenium bulbiferum* can be divided into three periods characterised not only by differences in external morphology, but also by differences in response to stimulation and in cytology. In the first stage, while the frond is still curled, the sensitivity to gravity and light is less than during the middle period, when the frond is uncurling and when the irritability both to light and gravity is at a maximum. In the third stage, when the frond has uncurled, geotropic irritability has stopped and irritability to light soon does so. The development of statocyte tissue runs parallel with the development of geotropic irritability. In the first stage the statocyte tissue is increasing to a maximum which is reached in the middle period, while by the time the frond has uncurled the statocytes have disappeared.

The relation between the presence of starch grains in the endodermis of members of the Compositæ and their ability to react to gravity has been examined by Clara Zollikofer, particularly in the case of *Tagetes*. ("Über das geotropische Verhalten entstärkter Keimpflanzen und den Abbau der Stärke in Gramineen-Koleoptilen," *Ber. deut. bot. Ges.*, **36,** 30–38, 1918.) If young seedlings up to four days old are placed in the dark for three or four days the starch in the hypocotyls disappears.

At the same time the hypocotyls lose their geotropic irritability, although they are still able to respond to changes in light and are still able to elongate. On replacement in the light the statolith starch grains are re-formed after one and a half to two days, and at the same time the organ regains its ability to respond to gravity.

Investigations have been made by a few workers with a view to determining whether geotropic curvatures can be correlated with other changes in the curving organ. Thus A. Tröndle ("Über die ersten Stadien der geotropischen Krümmung," *Vierteljahrssch. der Naturf. Ges. in Zürich*, **62**, 371–377, 1917) treated seedling roots of *Lupinus albus* with a 2N to 4N solution of sodium chloride after the roots had exhibited a geotropic curvature. This treatment brought about a lessening of the curvature, and the curvature was completely removed if the radius of curvature was greater than 14 millimetres. On the contrary, if the curved roots were treated with boiling water instead of the strong salt solution, the curvature remained. Treatment of unstimulated roots with the strong salt solution and with boiling water produced in each case a shortening of the root, but in the case of the former the reduction in length was about three times as great as in the latter. Tröndle concludes from these results that in the first stage of geotropic stimulation there results a difference in the elasticity of the cell walls on the two sides (upper and lower) of the root, so that if the turgor of the cells remains the same a curvature must result.

T. G. Phillips ("Chemical and Physical Changes during Geotropic Response," *Bot. Gaz.*, **69**, 168–178, 1920) examined the upper and lower sides of *Vicia* and *Zea* undergoing geotropic curvature with regard to differences in composition of the two sides. Water content, acidity as determined by titration, distribution of sugars and nitrogen compounds, and katalase activity were determined, but the author concludes that the curvature cannot be correlated with any of these. On the other hand E. O. Schley (*Bot. Gaz.*, **70**, 68–91, 1920), in a similar investigation, found there was a change of polysaccharides into sugars on the convex side, while a temporary increase of osmotic concentration on this side was also found. The respiration in a curving shoot is also greater on the convex side. The author concludes there is a definite sequence of changes in a shoot subjected to geotropic stimulation, these being (*a*) increase in respiration, (*b*) increase in acidity, (*c*) increase in turgor, (*d*) increase in hydrolysis of polysaccharides on the convex side.

A curious case of reaction to the gravitational stimulus has been recorded by H. Coupin ("Sur une tige à géotropisme horizontal," *Comp. rend. acad. sci.*, **172,** 608–610, 1921). This worker found that the stems of lentils germinated in the dark took up a horizontal position, and that if displaced into the vertical they curve so as again to lie horizontally. If they are illuminated, however, they soon bend into a vertical position and grow upwards in the ordinary way.

With regard to the reaction of plants and plant organs to light, one of the questions that has received some attention is whether it is the direction of the light, or differences in the intensity of illumination, bringing about differences in growth, that determines the phototropic reaction. The latter view, due to Blaauw, has found supporters in W. Nienburg (" Über phototropische Krümmugen an längseitig zum Teil verdunkelten Avenakoleoptilen," *Ber. deut. bot. Ges.*, **36,** 491–500, 1918) and J. Buder (" Neue phototropische Fundamentalversuche," *Ber. deut. bot. Ges.*, **38,** 10–19, 1920). Nienburg repeated the experiments of Charles Darwin of exposing etiolated and partially blackened seedlings of *Avena* and *Phajus* to light, using instead of the light from a window an artificial source of light, and screens throwing a sharp shadow so as to prevent diffuse light from reaching the shaded side. Out of 125 coleoptiles of *Avena* used, 91 curved towards the illuminated side and away from the darkened side, but only two actually curved towards the source of light. This result is held to afford confirmation of Blaauw's view that it is the quantity of light, and not the direction of the light, which determines the curvature. Buder also worked with *Avena*, and in addition with *Phycomyces*. Thin pencils of light were allowed to fall from above on to one side of the coleoptile apex of *Avena*, as a result of which curvatures resulted which were independent of the direction of the light. Also illumination of the coleoptile from either side brought about the same curvature, although the direction of the light is reversed in the two cases. Other writers on this question are H. Sierp (" Über den Einfluss geringer Lichtmengen auf die Zuwachsbewegung der Koleoptile von Avena sativa," *Ber. deut. bot. Ges.*, **37,** 123–128, 1919) and H. Lundegårdh (" Die Bedeutung der Lichtrichtung für den Phototropismus," *Ber. deut. bot. Ges.*, **37,** 225–236, 1919), the former a supporter to some extent of Blaauw's theory, the latter a supporter of the " light direction " theory.

An interesting paper by A. Páal (" Uber phototropische Reizleitung," *Jahrb. f. wiss. Bot.*, **58,** 406–458, 1918) dealt with the conduction of the phototropic stimulus in the coleoptile of *Avena*. The upper 3 to 5 millimetres of an etiolated coleoptile of *Avena sativa* 1·5 to 2 centimetres long was cut off, and then fastened on again into its original position by means of 10 per cent. gelatine ; the upper part was then illuminated on one side, while the lower part and the part at which the cut was made were kept in the dark. After six to ten hours the basal part had curved towards the source of light. This most interesting result indicates that it is not necessary to have continuity of intact cells for the conduction of the stimulus. The conduction of the stimulus is regarded by the author as brought about by the diffusion of dissolved substances. This view is similar to that held by a number of physiologists to account for the transmission of the stimulation in the case of the sensitive plant.

The response of motile organisms to light has been the subject of investigation by a number of workers. Miss R. Bracher ("Observations on *Euglena deses*," *Ann. of Bot.*, **33**, 93–108, 1919) found that a *Euglena* that inhabits the mud of the estuary of the Bristol Avon is visible on the surface of the mud during the day, but disappears under the surface at night, and that this phenomenon can be reproduced at will by placing the organisms in the dark. The action of light on the movement of a number of motile organisms was examined by Elizabeth Bolte ("Über die Wirkung von Licht und Kohlensäure auf die Beweglichkeit grüner und farbloser Schwarmzellen," *Jahrb. f. wiss. Bot.*, **59**, 287–324, 1920). These organisms are described as positively and negatively photokinetic according as light or darkness induces movement. The following were found to be positively photokinetic: *Chlamydomonas variabilis*, *Carteria*, some species of *Euglena*, *Trachelomonas* and members of the Volvocaceæ; while among negatively photokinetic forms were other species of *Chlamydomonas*, *Hæmatococcus*, and *Phacus*. Some species were found to be indifferent, among these being *Euglena hyalina*, *E. proxima* and *Chilomonas*. R. Harder ("Über die Reaktionen freibeweglicher pflanzlicher Organismen auf plotzliche Änderungen der Lichtintensität," *Zeitsch. f. Bot.*, **12**, 353–462, 1920) has investigated in detail the effect of change i light intensity on the motion of *Nostoc* hormogonia. When the light intensity is decreased there results a reversal of the motion. For this reaction there is required a definite presentation time of the original stronger illumination, and also a definite presentation time of the weaker light. These two presentation times bear to one another an approximately inverse relation, but not exactly so, the product of the two times decreasing with increase in the value of the presentation time of the original light. The intensity of the original light also has an influence on the response, for with more intense illumination the sensitivity of the hormogonia is reduced, so that there may result an increase in the presentation time of the weaker light. Thus if the intensity of illumination was increased and the presentation time reduced so that the total quantity of light was maintained constant, the subsequent presentation time in weaker light increased with increase in intensity of the original light. Three stages could be observed in the response: a slowing down of the original movement, a rest period, and recommencement of movement, but in the opposite direction.

Movements which at first sight appear to be regulated by light, but which in reality are dependent upon temperature, have been investigated by Lundegårdh ("Über Blütenbewegungen und Tropismen bei *Anemone nemorosa*," *Jahrb. f. wiss. Bot.*, **57**, 80–94, 1917). The mature flowers of *Anemone nemorosa* are fully opened and turned towards the sun at midday, while at night, or in rainy weather, they are closed and bent downwards. Lundegårdh finds these movements are not dependent on light but are thermonastic. The flower stem is, nevertheless, strongly phototropic. The thermonastic movements occur both in the flower and the flower stalk, the flowers opening when the flower stalk is just erect, and closing when the stalk begins to curve. These nastic movements are stopped by anything which brings about a cessation of growth, whence it is concluded that they arise by growth differences, and not by different turgor conditions in the cells on different sides of the organs.

A long investigation on thermotropism has been made by R. Collander (Dissertation, Helsingfors, 95 pp., 1919). Shoots of seedlings of *Avena*, *Helianthus*, *Lepidium*, *Vicia*, and *Zea* all exhibited positively thermotropic curvature, probably due to slower growth on the concave than on the convex side. These curvatures were only observed at temperatures above the optimum for growth. Radicles exhibited a positively thermotropic curvature at lower temperatures and a negatively thermotropic curvature at higher temperatures. Even the positive curvature is preceded by a negative one. No thermotropic curvature was observed in *Phycomyces*.

In this last-named fungus Elfving had shown as long ago as 1890 that a number of substances could bring about a chemotropic curvature of the sporangiophore. The same worker has now shown that this curvature is in reality an aerotropic one, that is, one due to a change in composition of the atmosphere. ("Phycomyces und die sogenannte physiologische Fernwirkung," *Ofvers. Finsk Vet. Soc. Forh.*, **59**, Afd. A, No. 18, 56 pp., 1917). The "metallotropic" curvatures induced by iron and other metals are produced partly by absorption of gases from the surrounding air, partly by oxidation of the metals which is probably accompanied by the formation of ozone. Many odoriferous substances are capable of inducing similar curvatures.

**ANTHROPOLOGY.** By A. G. Thacker, A.R.C.S.

In the *Journal of the Royal Anthropological Institute* for the first six months of last year (vol. li) there are several papers of more than usual interest. F. G. Parsons has an article "On the Long Barrow Race and its Relationship to the Modern Inhabitants of London." This paper is an elaborate reply to some rather startling conclusions set forth by the late Dr. Macdonell in *Biometrika* as long ago as 1904. Dr. Macdonell averred that a series of London crania, dating from the seventeenth century A.D., showed that the Londoners of that period were "closer to the Long Barrow British than to the Round Barrow British, Romano-British, Anglo-Saxon, or the Medieval English which are represented in our museums." And in this opinion Dr. Macdonell appears to have had the support of Prof. Karl Pearson ; and, as Mr. Parsons points out, it is somewhat surprising that such a startling view did not attract wider attention. Mr. Parsons makes a detailed comparison of these seventeenth-century London skulls with a series of about twenty Long Barrow skulls and with a series of Anglo-Saxon skulls, and he comes to the conclusion that Dr. Macdonell was entirely in error, and that the London crania were very much nearer to the Anglo-Saxons than to the Long Barrow men. Mr. Parsons makes out a very strong case for this view, which is in accord also with the inherent probabilities of the matter.

Another article is by Sir Henry Howorth and is entitled "Buddhism in the Pacific." This will be found extremely interesting. The article begins by explaining the two methods of accounting for close and detailed resemblances between cultures, or parts of cultures, in widely separated areas, namely, the conception that such resemblances are due to human minds meeting the same difficulties and problems—quite independently—in the same way (a process which is the exact analogue of what zoologists call convergence), and the other and more natural theory that the resemblances are due to contact and the grafting of one culture upon another. Sir Henry Howorth is entirely in favour of the latter theory as a general principle. He says : "It is, I hold, *prima facie* improbable that the same concrete idea should have arisen and been adopted by entirely separate races, except in extremely rare cases, and for myself I could not be induced to adopt the theory in question as a *vera causa* until every possibility of a graft having occurred had been exhausted." The author then describes the long voyages which the Polynesians, Chinese, and Japanese used to make in the Indian and Pacific Oceans before the coming of Europeans. He then proceeds to discuss a particular and striking case of "a graft," namely, the occurrence in the Hawaiian Islands of special helmets and other garments characteristic of Tibetan Lamas—though, in the nature of the case, not constructed of the same materials in the two cases.

This number of the *Journal* also contains the Presidential Address of Sir Everard F. im Thurn, which was entitled, "On the Thoughts of South Sea Islanders." The address is very short, but contains some interesting comments on the friendliness of South Sea cannibals in the very early days of their contact with Europeans.

The following articles may also be noted :

In *J.R. Anth. Inst.*, vol. li : "The Older Palæolithic Age in Egypt," by Dr. C. G. Seligman ; "Excavations at the Stone-axe Factory of Graig-lwyd, Penmaenmawr," by S. H. Warren ; and "Some Early British Remains from a Mendip Cave," by Dr. L. S. Palmer.

In *Annals of Archæol. and Anthropol.*, vol. viii (University of Liverpool) : "Oxford Excavations in Nubia," by F. L. Griffith ; and "Ancient Piracy in the Eastern Mediterranean," by H. A. Ormerod.

And in *Man* : "The Hybrid Origin of the Mediterraneans," by Prof. V. Giuffrida-Ruggeri (December 1921) ; "A New Find in Palæolithic Cave Art," by M. C. Burkitt (December 1921) ; and "The Ice-Age and Man," by H. J. E. Peake (January 1922).

## MEDICINE. By R. M. Wilson, M.B., Ch.B.

The first volume of the reports of the St. Andrews Institute for Clinical Research, which was founded two years ago by Sir James Mackenzie, is of great interest. It reveals the general practitioner of medicine as a research worker of great acumen, and also shows how important to the study of both health and disease are the observations gleaned by a trained clinician at the bed-side.

Perhaps the most considerable contribution in the volume is that dealing with symptoms as modifications of ordinary reflexes. A great deal of misapprehension seems to have sprung up in regard to this matter, and therefore the paper by Dr. Hering, Professor of Physiology at St. Andrews University, in which the reflex theory of symptoms is described and discussed, is very welcome.

Dr. Hering points out that the St. Andrews view differs from that in common currency owing to its inclusion of sensations among reflex phenomena. Voluntary muscular action, he indicates, becomes, when regarded in this fashion, a reflex to some stimulus which has called it forth, and consequently the feelings accompanying responses to stimuli partake in the reflex character of the responses themselves.

It may not at first sight seem that there is anything very unusual in this idea. Yet in point of fact it is of a most revolutionary character. Because many ailments show themselves in the first instance as modifications of sensation—for example, as pain or exhaustion—and if we are able to determine which reflexes have been disturbed or modified in order to produce them, we are a long way on the road leading to recognition of the primary cause of the disease. We are, too, approaching a position at which new light on mental processes may await us.

The accepted view of a reflex act excludes consciousness and so separates mental from physical life. The St. Andrews view brings these two into close approximation by regarding consciousness as, in part at least, an expression of physical achievement or physical failure. For pain and exhaustion are both conscious feelings.

In the physical realm too a correlation of organic function is effected the moment symptoms are looked on as modifications of the normal. If, for example, we take such a condition as palpitation of the heart, we perceive that it may have many entirely different causes and that the majority of these will lie outside of the heart itself. For the normal reflex, which results in a more active beating of this organ, can, clearly, be modified at several different places, at the periphery, centrally, and along the course of the nerves, as well as in the cardiac area. Thus poisoning with, for example, alcohol or the toxins of disease is brought into relation to such a localised condition as a primary myocarditis.

From the point of view of the physician the distinction between one kind of interference with the reflex and another kind will be made in terms of associated phenomena—by means of what Sir James Mackenzie calls "the law of associated phenomena." For symptoms occur "not in single spies, but in battalions"—if only we were capable of recognising them.

This work represents a definite pushing out into the uncharted country of disease, a country which can be known only by the unaided senses. It is the claim of those who are carrying on the work that it demands for its successful accomplishment the peculiar opportunities and circumstances of general practice.

. . . . . .

The appointment of an official committee to inquire into the effects of sunlight in health and disease marks a step in the direction of a new understanding of environment as it affects human welfare. The committee consists of Prof. Bayliss, F.R.S. (chairman), Mr. J. E. Barnard, Dr. H. H. Dale, F.R.S., Capt. R. S. Douglas (late I.M.S.), Sir Henry Gauvain, M.D., Dr. Leonard Hill, F.R.S., and Dr. I. H. Sequeira, F.R.C.P. Dr. Edgar Schuster is the secretary. The recent work of Sir Henry Gauvain at the Lord Mayor Treloar's Cripple Home at Alton, Hants, on surgical tuberculosis has shown how great an effect on this disease sunlight is capable of producing. Similar favourable reports have been received from many of the Alpine sanatoria. Consequently the new committee should find plenty of material on which to work.

# ARTICLES

## THE GENERAL BEHAVIOUR OF OPTICALLY ACTIVE COMPOUNDS

By T. S. PATTERSON, D.Sc., Ph.D.

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When, in 1815, Biot first discovered that certain organic compounds have the power of altering the plane of polarisation of light, he thought this deviation was unaffected by change of temperature, and solvent, and concentration ; and he suggested the idea of a specific rotatory power for such a substance, which ought to remain constant under all conditions. But he was not long in discovering that his original notion was incorrect, and it has been shown in more recent years that the optical activity of a given compound is in general highly sensitive to external conditions ; that it may vary in perplexing fashion, and to a very considerable extent, according to the temperature, the solvent, the concentration, and the wave-length of the light used. Investigation, which generally follows the path of least resistance, was, not unnaturally, first directed to the influence of different solvents upon active compounds, but without any very satisfactory results ; and it was perhaps the examination of the rotation of active compounds at different temperatures, first taken up systematically by P. F. Frankland, which led in the end to conclusions of some general applicability. Some twenty or twenty-five years ago it was known that the rotation of a number of active substances often increased or decreased fairly rapidly with rise of temperature ; and the opinion tacitly held at that time, although perhaps not definitely expressed, was, probably, that the rotation gradually rises to some definite value, and thereafter remains practically constant, as shown in Fig. 1, by the curve DEFGHKL. In 1896, however, Frankland and Wharton (*J.C.S.*, 1896, **69**, 1587) first demonstrated that this is not the case, since they found in the curve for ethyl dibenzoyltartrate in the super-fused homogeneous ester at a temperature of 60°, a distinct minimum[1] specific rotation of −62·3°. It was then noticed by the present writer that a similar behaviour is found in solutions of sodium and potassium tartrates as well as of potassium-methyl tartrate, potassium-ethyl tartrate, and potassium-*n*-propyl tartrate, which all exhibit a maximum [1] in their T–R [2] curves for certain concentrations; and that the position of this maximum varied with the concentration, passing gradually to a higher value and occurring at a lower temperature as the concentration diminished. Fig. 2 shows this in the case of potassium-ethyl tartrate. (*J.C.S.*, 1904, **85**, 1117–1125.) It thus appeared that the graph representing the relationship of temperature and rotation might be two-limbed, as DFHNOP in Fig. 1, and this at once reconciled what had at first (*J.C.S.*, 1901, **79**, 171–173) been regarded as very contradictory behaviour, namely, that although the rotation of homogeneous ethyl tartrate increases on heating, that of a

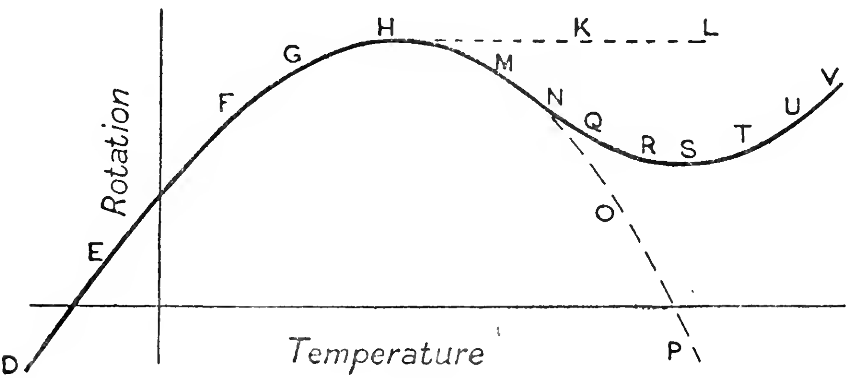



FIG. 1.

dilute aqueous solution diminishes; for if the extended T–R curve be two-limbed with a maximum, then the curve for the homogeneous ester might represent one limb, the ascending one approaching a maximum, whilst that for a dilute solution would represent the other, the descending limb of the curve, the maximum having already been passed at a fairly low temperature. The existence of a maximum was then observed in other cases, having the value and occurring at the temperatures shown in the following table:

| | *T* | *Max* $[M]_D$ |
|---|---|---|
| Ethyl tartrate | 175 | 30·9 |
| *n*-Propyl | 150 | 41·6 |
| Sec. | 144 | 58·03 |
| *Iso*butyl | 120 | 53·9 |
| Benzyl | 115 | 72·8 |

(*J.C.S.*, 1913, **103**, 149.)

[1] The occurrence of a minimum is, of course, exactly the same kind of phenomenon as the occurrence of a maximum.

[2] Temperature—Rotation.

It will be noticed that, roughly speaking, the maximum rotation increases in value and moves towards lower temperatures just as is the case with solutions of the tartrates. Apparently, therefore, the comparatively slight change of composition in passing from, say, ethyl tartrate to *n*-propyl tartrate brings about a corresponding, comparatively slight, shift in the point of maximum rotation, in much the same way that increasing dilution alters the position of the maximum in the T–R curves for potassium-ethyl tartrate, Fig. 2.

That this behaviour is important will appear from the con-

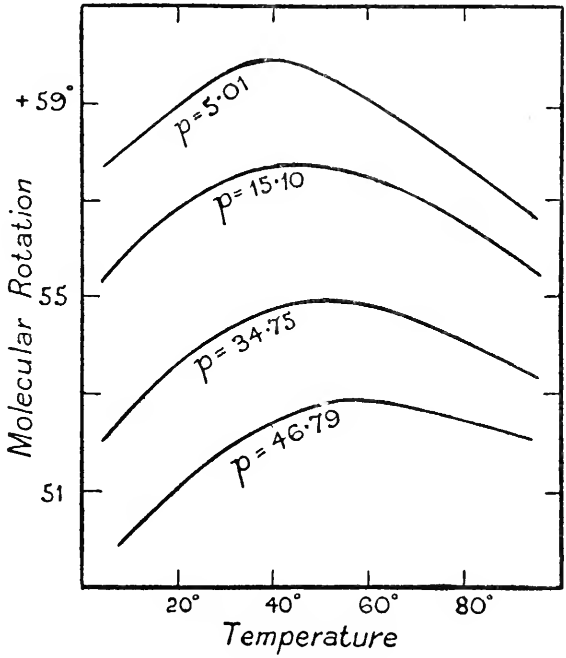



FIG. 2.—Potassium-ethyl tartrate in water.

sideration that maxima in curves are singular points and may be taken, at least as a first approximation, to represent corresponding conditions in the two different—but related—substances to which they pertain. They therefore present some kind of basis upon which comparison might perhaps be instituted.

It has already been mentioned that solution in water alters the position and value of the maximum rotation in ethyl tartrate. It was found, later on, that some other solvents are even more powerful in the same direction, whereas others, again, show an opposite behaviour.

To the first class belong water, nitrobenzene, the nitrotoluenes, benzaldehyde, and other substances (*J.C.S.*, 1908, **93**, 1846), and it seems clear that amongst solvents generally the power to raise the rotation of the dissolved ester involves also a passing of the maximum in the T–R curve towards lower temperatures as is shown in Fig. 3. Thus both for one substance in different solvents and for different, but related, substances in the homogeneous condition a similar behaviour is observed:

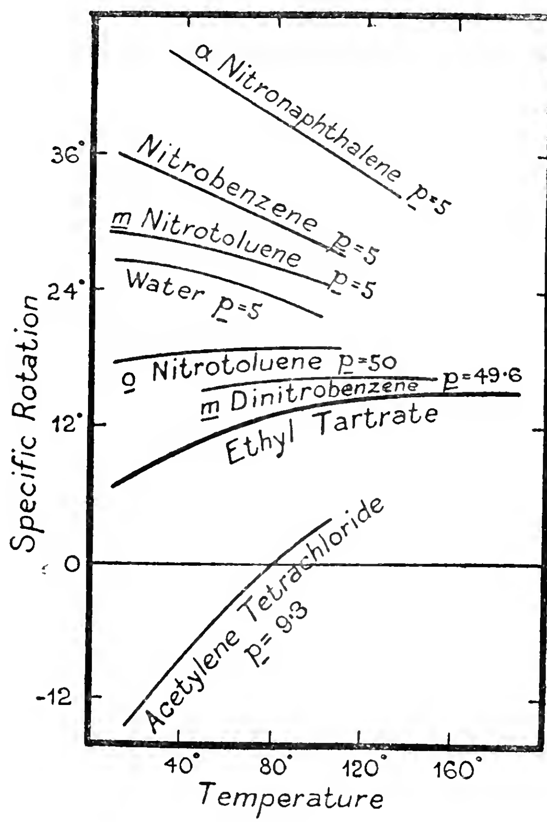



FIG. 3.

the maximum in the T–R curves occurs at a lower temperature the greater its rotation value—it passes gradually towards the top, and to the left, of the diagram. On the other hand, when a solvent such, for example, as chloroform, ethylene bromide, or acetylene tetrabromide depresses the rotation of the ethyl tartrate the opposite would appear to be the case, although, since the maximum in homogeneous ethyl tartrate occurs at the already fairly high temperature of 175°, it is difficult actually to observe the occurrence of the maximum in such solutions at still higher temperatures.

We thus arrive at a generalisation which appears to be of a fairly comprehensive character : *The T–R curves for the simple tarrates exhibit maxima. In solvents which have the power of raising the rotation of the dissolved active ester this maximum, with an increased rotational value, occurs at temperatures lower and lower in proportion to the power of the solvent, and vice versâ.*

One solvent which, when it was first examined, did not seem to conform to this regularity was quinoline (*J.C.S.*, 1909, **95**, 32–40) ; ethyl tartrate dissolved in it gave rotations higher than that of the pure ester and, on heating, the rotation diminished ; but the form of the curves was peculiar, being convex to the point of origin of the diagram instead of concave as in the other cases. Later on, however, it was observed that the T–R curves for ethyl di-monochloracetyltartrate and *iso*butyl di-trichloracetyltartrate both exhibit distinct minima in their molecular rotation, the value of which for the former is + 66° at a temperature of 54°, and of the latter + 88° at a temperature of + 105° (*J.C.S.*, 1912, **101**, 378, 380). In all three cases the *shape* of the curves obtained corresponded to the part QRST in Fig. 1.

Now it seems reasonable to suppose that the T–R curves for ethyl tartrate and for ethyl di-trichloracetyltartrate must be related to one another in some way, however remote ; and in a later paper (*J.C.S.*, 1913, **103**, 153) the suggestion was made that just as a slight change of constitution, in passing, say, from ethyl tartrate to *n*-propyl tartrate, causes a slight shift in the T–R curve so that the maximum is moved to a lower temperature but with a higher value, the much greater change of constitution in passing from ethyl tartrate to ethyl di-trichloracetyltartrate may have caused a much greater shift in the curve in such a way that the maximum had passed entirely out of the region of medium temperatures, and may have brought into view not merely the descending part of the curve which had previously been supposed two-limbed, but a new minimum which in the homogeneous simple ester (ethyl tartrate), or in tartaric acid, could only be observed at temperatures impossible to attain to. In other words, that the curve, when produced to the right of the maximum, would develop into one showing a minimum rotation. The extended T–R curve for ethyl tartrate then would have a sinuous form exhibiting both a maximum and a minimum as is shown in Fig. 1, DFHNSV, and it would be this same minimum which is brought into view when the simple ester is either converted into its di-trichloracetyl derivative or when it is dissolved in quinoline, whence it would appear that the solvent influence of quinoline is especially powerful and of much the same effect as a very considerable change of constitution. The effect of change of constitution therefore, or of change of solvent, would appear to be a shifting of a fundamental type of sinuous curve so as to bring different parts of it into the region of medium temperatures, but, of course, with modifications, often very considerable, of the actual values of the rotations.

But in passing from a maximum in a curve to a minimum there must be, somewhere, a point of inflection, and in fact a number of points of inflection had already been noticed, particularly in the curves for solutions of ethyl tartrate in water for all dilutions less than about 50 per cent. (*J.C.S.*, 1904, **85,** 1129), as well as in other instances ; the curves obtained in these cases being of the shape of the part HMNQ of the curve in Fig. 1, which shows a point of inflection at N. Presumably, therefore, they correspond to this part of a general curve. Assuming, then, from the evidence adduced above, that the T–R curve for homogeneous ethyl tartrate, if the ester were heated over a range of temperature of, say, –50° to 500°, would have the form DFHNSU, shown in Fig. 1, we find that solution in water and nitro-benzene moves the maximum which occurs at H in the homogeneous ester towards lower temperatures and higher values. Solution in acetylene tetrachloride moves the maximum at H in the opposite direction. Solution in water (p : 25) brings into view a part of the curve HMNQ which just exhibits the point of inflection at N. Solution in quinoline alters the substance to such an extent that the part QRST comes into view, and in a similar manner when ethyl tartrate is converted into ethyl di-trichloracetyltartrate this same part of the general curve comes into the region of ordinary temperatures. Summing up the evidence leading to this conclusion, we have therefore the following experimental facts: (1) The occurrence of maximum rotations. (2) The transference of this maximum in varying degrees from higher to lower temperatures or vice versâ in accordance with—(*a*) The nature of the solvents ; (*b*) the concentration in a given solvent ; (*c*) change of constitution of the active substances. (3) The occurrence of minima in the T–R curves for derivatives of substances themselves showing a maximum. (4) The occurrence of points of inflection in T–R curves, which presumably would be found to connect together a maximum and minimum if the curve could be sufficiently extended, which for the most part it cannot. Such a curve as this would apply to a single colour of light. If other colours of light be used, it is found that the T–R curves obtained for homogeneous ethyl tartrate intersect one another (*J.C.S.*, 1913, **103,** 164; 1916, **109,** 1145) in a manner which is sufficiently represented for our present purpose by the parts of the curves in Fig. 6, lying between E and H. In most, if not in all, cases that have been investigated, the T–R curves for three or more colours of light do not intersect at one point, but over a range, and it is this relative displacement of the T–R curves which gives rise to what is known as anomalous rotation dispersion, a phenomenon which will be referred to in the sequel. In the meantime it is to be observed that the point at which two T–R curves cut one another, as, for example, at G in Fig. 6, may also, like a maximum, be regarded as a singular point. It is therefore of great interest that, in much the same way as the maximum is displaced in accordance with the changes of constitution of an active substance or with a change of solvent or of concentration, the point at which two given temperature rotation curves cut one another shifts at least in the case of tartaric acid (*J.C.S.*, 1913, **103**, 167) and *iso*butyl tartrate (*J.C.S.*, 1916, **109**, 1147), in a somewhat similar manner; but with this difference, that although the intersection of the T–R curves may occur at some different temperature with change of solvent, etc., its rotation-value remains either constant or nearly so (see *J.C.S.*, 1916, **109**, 1158). Much the same thing obtains with regard to the whole region of so-called anomalous dispersion as far as the matter has been investigated, and since the region of anomalous dispersion shifts about with change of constitution or solvent in much the same way as the maximum, it is a further important piece of evidence that the whole T–R curve is being subjected to this kind of change. Exactly the same sort of thing as had been found for ethyl tartrate occurs in the case of *iso*butyl tartrate. In *iso*butyl tartrate a maximum rotation occurs at a temperature of about 150° for all the different colours of light, and since the ester will not remain superfused for a sufficiently long time, it is not possible in the homogeneous ester to observe the region of anomalous rotation dispersion. But by using a solvent such as acetylene tetrachloride, which has a depressing effect upon the rotation of the tartrate, it is possible to bring the region of anomalous dispersion within the ordinary range of temperature. Thus, the maximum rotation and the regions of anomalous dispersion can both be moved about in accordance with the solvent used, and, as far as can be judged at present, on esters of similar constitution a given set of solvents would have much the same relative influence (*J.C.S.*, 1916, **109**, 1147).

The T–R curves for ethyl tartrate for eight different colours of light have been examined over a wide range of temperature (*J.C.S.*, 1916, **109**, 1145). They intersect one another as has been described, and the question then naturally presents itself, that if the curve for one of these colours, say sodium yellow, has the sinuous form shown in Fig. 1, which appears to be indicated by piecing together, as above, evidence of different kinds, what relationship will be maintained amongst these curves if the examination of the substance could be extended over a further temperature-range of, say, 200° ?

As has already been explained, from the behaviour of ethyl tartrate in quinoline solutions, and the rotation of ethyl di-trichloracetyltartrate, it is to be expected that each curve will tend towards a minimum, and it is of much interest to ascertain the sequence, in that region of the T–R curves, of the absolute values of the rotation for the various colours of light. At the maximum already discussed (H in Figs. 1 and 6), the rotation-value is greatest for violet and least for red ; at the minimum (S in Fig. 1), it might perhaps be expected that the opposite

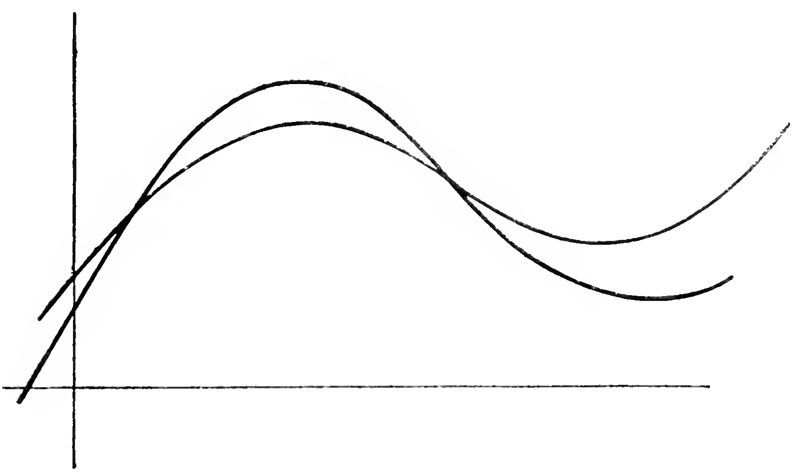


FIG. 4.

should be the case. But if this were the fact it would be necessary for the T–R curves to cut one another again between the maximum and the minimum values. Since these curves actually do intersect in this manner at medium temperatures, before the maximum at H (Fig. 6) is reached, there is nothing inherently improbable in the suggestion that they may cut one another again after the maximum is passed and before the minimum is reached, and thus give rise, perhaps, to a second region of anomalous dispersion. This possibility is indicated in Fig. 4. In order to determine the question an attempt was made to follow the T–R curves for ethyl tartrate dissolved in quinoline to as high a temperature as possible, but although the curves approached one another towards the minimum, they showed no signs of actual intersection. The scale diagrams will be found elsewhere (*J.C.S.*, 1916, **109**, 1145, 1147 ; *Proc. R.S.E.* 1918–19,

**39,** 23); it will suffice for present purposes to say that they very closely resemble in general appearance the parts NQRS of Fig. 6. The dispersion at the minimum seems, therefore, to be positive just as it is at the maximum, whence it appears that the dispersion may maintain its character over a range of temperature which includes both a maximum and a minimum. But although intersection apparently does not occur between the maximum at H and the minimum at S (Fig. 6), it might be that the T–R curves would cut each other on the farther side of the minimum, as is indicated in Fig. 5. This question, as well as the previous

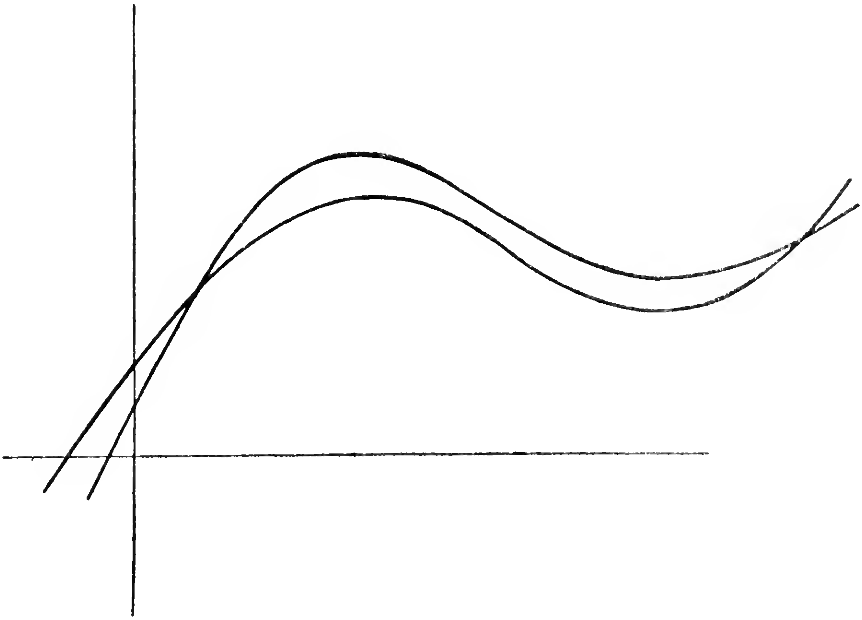


Fig. 5.

one, was therefore investigated by an examination of the T–R curves in the case of homogeneous *iso*butyl diacetyltartrate, which exhibits, like the di-trichloracetyl derivative, a minimum at medium temperatures—a minimum which presumably corresponds to that found in the curves for ethyl tartrate dissolved in quinoline, since the dispersion in that region in both cases is of the same character. Examination of the rotations of this ester from $-20°$ to $+200°$ for six colours of light (*J.C.S.*, 1916, **109,** 1155) revealed a distinct minimum in each of the curves, which, like those for ethyl tartrate dissolved in quinoline, show no sign of intersection before the minimum is reached, and it is also clear that after passing the minimum value they again pursue a course which evidently would not lead them to cut one another. It therefore appears that the T–R curves for an active substance of the type with which we are dealing would not have the appearance of Fig. 5, but rather that shown by the part of Fig. 6 from D to V, the curves probably tending to some other maximum, which so far cannot be reached.

It is natural now to wish to extend this investigation towards the low temperature end of the diagram. The rotation of homogeneous ethyl tartrate for all colours of light diminishes very rapidly as the temperature falls below zero : it is unlikely that this should continue indefinitely, and, just as a maximum

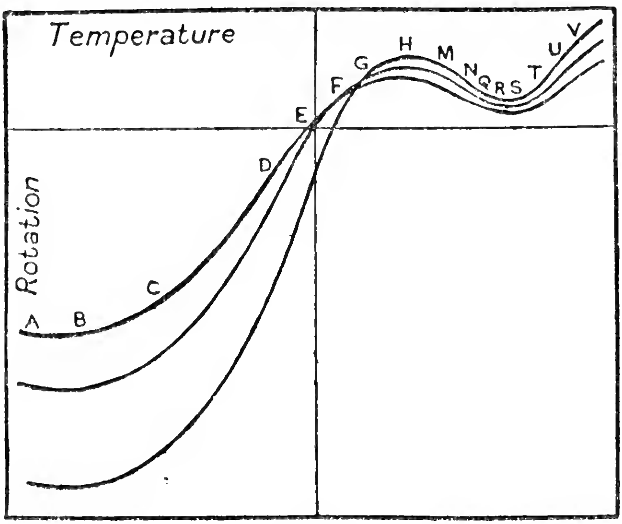



Fig. 6.
The curve of greatest amplitude pertains to violet light, that of least amplitude pertains to red light.

was found at higher temperatures, a minimum of low value is to be expected at low temperatures, a minimum doubtless corresponding to that found by Frankland and Wharton (*loc. cit.*) in the curves for ethyl dibenzoyl tartrate at medium temperatures ; the behaviour of the dibenzoyl ester thus indicating the behaviour of the parent ester at very much lower temperatures.

A definite decision on this point could not be come to from an examination of T–R curves for a single colour of light, but a much more definite conclusion can be drawn if light of different refrangibilities be used. Thus, if the minimum actually observed in ethyl dibenzoyltartrate at a temperature of about 60° corresponds to the minimum which, presumably, exists in ethyl tartrate at a high temperature, namely to the region QRST in Fig. 6, then the dispersion might be expected to be of the same type in both cases, namely positive—the rotation for violet should be greater in an absolute sense than for red. But if the minimum were such as might be expected by continuing the ethyl tartrate curves towards low temperatures, the rotation for red light should have a higher absolute value than the rotation for violet light, the dispersion being thus negative. This point was therefore investigated by an examination of homogeneous *iso*butyl dibenzoyltartrate, for six colours of light and for temperatures between 0° and 180° (*Proc. R.S.E.*, 1918–19, **39**, 26, 32), when curves were obtained corresponding very closely to those between A and C, Fig. 6. There was a minimum in each curve, and the absolute value of the rotation was greater for red than for violet. The dispersion is thus negative, and the minimum observed in this region could therefore hardly correspond to the minimum in the neighbourhood of S in Fig. 6. It may therefore be concluded, until some better suggestion can be made, that the general relationship between temperature and rotation for ethyl tartrate, and therefore, with minor modifications, for other tartrates, over a very wide range of temperature is represented by the curves in Fig. 6. At quite a low temperature the dispersion is visibly normal[1] but negative; at temperatures between about zero and 90° the dispersion is visibly anomalous; beyond that the curves rise to reach a maximum; they then fall to a minimum, which apparently does not go below zero, and then rise again, presumably to reach another maximum, all without actual intersection, and therefore without visible anomaly in the dispersion.

Two other points may be dealt with in this connection. It has long been obvious that the so-called dispersion coefficient for any given substance has no practical value. This coefficient, which is simply the value of the rotation for one colour of light divided by the value of the rotation for another colour of light—usually for violet divided by yellow or green divided by red, etc.—naturally does not show any very marked variation at different temperatures for any substance which has a high rotation, positive or negative. Thus, for example, the dispersion coefficient measured in the ordinary way on the curves of Fig. 6 at A, B, or C would probably not differ very greatly. But it will be obvious that dispersion coefficients taken from E to H

[1] This means merely that to the eye the magnitude of the rotation is in the same order (or the inverse) of the magnitude of the wave-length. As nobody knows what normal rotation dispersion is, it is difficult to define the term except in a quite arbitrary manner. Consequently anomalous and abnormal rotation dispersion present equal difficulty in the way of definition.

would have all sorts of values from + infinity to − infinity. From H on to V the values found for the ordinary dispersion coefficient would at least remain of the same sign, which would be the opposite to that for the dispersion coefficient from D to A. It is clear, therefore, that so variable a quantity can be of little use. If, however, the ordinary zero of rotation be disregarded, and the dispersion coefficient be calculated, for any two colours of light, with reference to the point at which the T–R curves for these colours intersect one another taken as a rational zero, $z_0$, then it might be that some coefficient of a more constant character would be obtained ; it would at least be one which would not give positive, negative, infinite, and zero values, all for the same substance, in accordance with slight changes of temperature. Thus, for example, the violet/red dispersion coefficient at the point G would be

$$\frac{a_v - z_0}{a_r - z_0},$$

$a_v$ and $a_r$ being the rotations at the temperature corresponding to the point G, and $z_0$ being the value of the rotation at the point of intersection of the curves for violet and red light.

Values were calculated by the writer, in this way (*J.C.S.*, 1916, **109**, 1188, 1189), from data obtained by Pickard and Kenyon for methyl-*tert*butyl-carbinol and for *d*-1-naphthyl-*n*-hexyl-carbinol. The rational dispersion coefficient found for violet/green was very much better than that ordinarily employed, and, in the latter case, remained approximately constant over 200° of temperature, while the ordinary coefficient assumed all values between plus and minus infinity. This dispersion coefficient may therefore prove to be of considerable practical value, but the examination of active substances is not yet sufficiently complete, even in a few cases, to allow of much extension of the idea. Nevertheless, even in the case of ethyl tartrate, by using dispersion coefficients of this kind (*loc. cit.* 1191), a very much better constancy can be arrived at than by any other method.

A most interesting discovery was made by Armstrong and Walker (*Proc. R.S.*, 1913, [A], **88**, 392) when they found that the rotation values for certain substances could be plotted upon what they termed a characteristic diagram. Their procedure is to plot the values of rotation for several different colours of light against the value of the rotation for some other, reference, colour. The original method of Armstrong and Walker was modified by the present writer in a way which permitted the diagram to be considerably reduced in size (*loc. cit.*, 1181).

Degrees of rotation are marked along a horizontal reference line, say mercury green, and then vertically above or below any point on this line are plotted the differences between the rotations for other colours and the reference colour. It is then found that the experimental points for the various colours of light generally lie along straight lines which usually intersect one another and the reference line in the same neighbourhood, but never, as far as is known, at the same point. There thus appears amongst optically active compounds a uniformity of behaviour which was wholly unexpected, and wholly unpredicted, a comparatively short time ago; for it is found that the data obtained for some active substances such as, for example, methyl-*tert*-butyl-carbinol, in the homogeneous con-

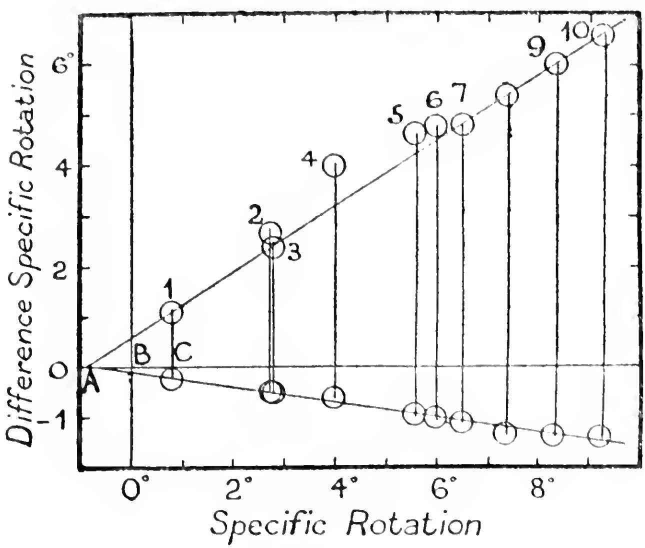
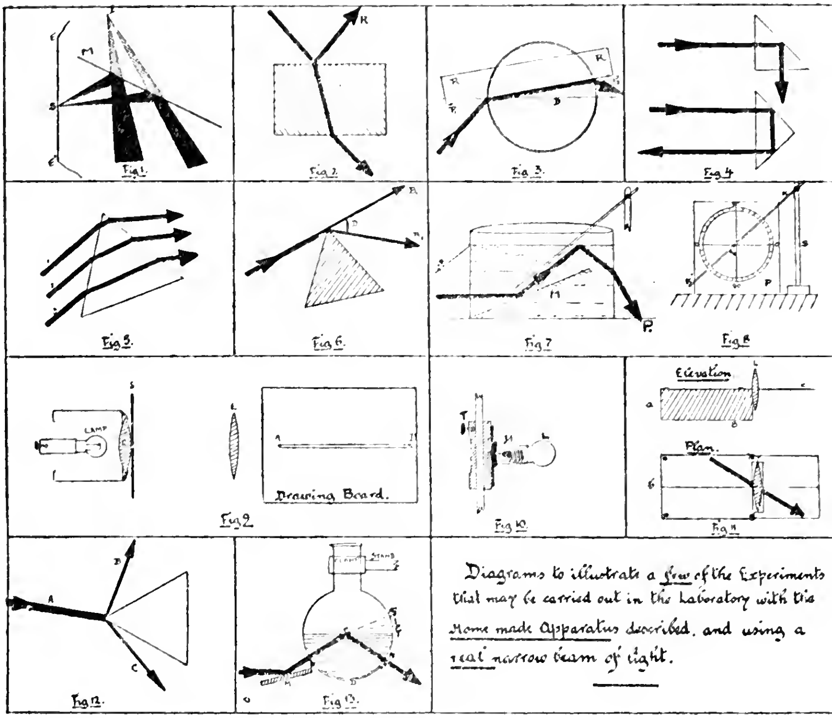



FIG. 7.
The upper inclined line is for mercury, violet; the lower for sodium, yellow.

dition at different temperatures, or in solution in different solvents at various concentrations and temperatures, and—what is even more remarkable—other derivatives of that substance, may all lie approximately upon the lines of one characteristic diagram.

Fig. 7 is the characteristic diagram for methyl-*tert*-butyl carbinol, drawn from Pickard and Kenyon's data by the author's method (*J.C.S.*, 1914, **109**, 1187). The points 1, 2, 3, 4, and 6 represent the rotation values for 5 per cent. solutions in chloroform, carbon disulphide, pyridine, benzene, and ethyl alcohol at the ordinary temperature, whilst 5, 7, 8, 9, and 10 are the data for the homogeneous substance at the temperatures, 100°, 80°, 60°, 40°, and 20° respectively. The three lines along which these




Diagrams to illustrate a few of the Experiments that may be carried out in the Laboratory with the Home made Apparatus described, and using a real narrow beam of light.

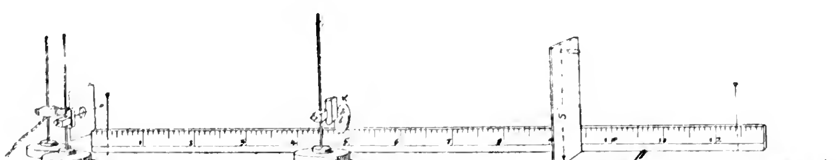



Fig 14.

Simple direct-reading Optical Bench consisting of metre rule resting on its edge and pinned to the table. By addition of a second rule it is easily extended to two metres or more.

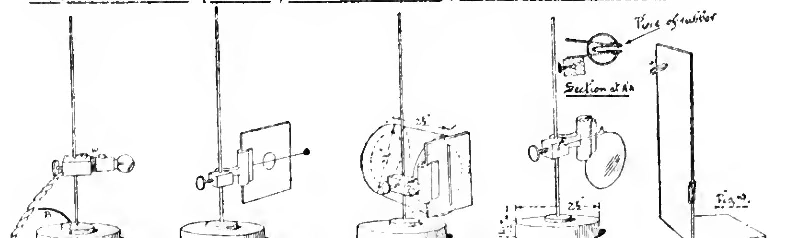



Fig 15. 4 Volt Lamp Holder

Fig 16. Aperture Clip

Fig 17. Condenser lens mounted in 6 tin with aperture clip attached.

Fig 18. Lens Holder. Section shows automatic grip of piece of rubber.

Fig 19. Aluminum Screen with clips for holding card.

# Home made Optical Apparatus.

data group themselves meet very nearly in one point, which is, however, not the zero of rotation. Now the actual rotation value at the point 1 is BC + C1, and the *v/g* dispersion coefficient by the ordinary method of calculation is $\frac{BC + C1}{BC}$. It is quite obvious that the coefficient calculated in this way from values lying along the line for mercury violet cannot remain constant. It is equally obvious, on the other hand, that the ratios such as $\frac{AC + C1}{AC}$ must remain constant. But the point A, which has the rotation value $-0{\cdot}9°$, is exactly that at which the temperature-rotation curves for these colours of light for that particular substance would intersect, the point which has already been suggested as the rational zero. The fitting into the characteristic diagram of data obtained from derivatives of some compound taken as mother substance is practically the same thing as the tracing of parts of temperature rotation curves ordinarily inaccessible, by examining the temperature rotation curves of derived substances ; and the characteristic diagram is thus also a very strong confirmation of the suggestion that dispersion-coefficients should be calculated with respect to a rational zero, since it is quite obvious that if, in fact, the data for two given colours of light for an active substance, for that substance in solution, for that substance at different temperatures, and for derivatives of that substance, also under these different conditions, all lie along two straight lines of a characteristic diagram which intersect at some point not zero,[1] the rotation for the other colours must remain constant throughout all that wide range, provided, and only provided, the rotation values are calculated with respect to the point of intersection and not with respect to the actual zero.

It will be seen, from what has been said above, that the work of the last ten years has introduced with an almost dramatic suddenness, into what was previously the very confused and difficult field of optical activity, an astonishing degree of uniformity and harmony.

[1] As far as we are aware, no instance is known at which such lines do actually intersect at zero, in the case of permanent rotation.

# THE PRESENT CONCEPTION OF MATTER

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For a great many years the dissipation of the world's available energy has been going on at an ever-increasing rate. Windmills, water-wheels, and human and animal labour have given place to steam and petrol engines and to other forms of mechanical power, with the result that the consumption of energy in the last century has not merely been doubled or trebled but has been increased almost indefinitely.

Our available capital of energy has been captured from the radiations of the sun by plants and stored in a chemical way as coal, oil, peat, etc. It has taken countless ages to accumulate and is limited in amount ; yet we use it as though the supply were inexhaustible. As a matter of fact, some of the coal-fields of the world have already come to an end, and it is estimated that many of the oil-fields will last only a comparatively few years more. On the other hand we have an annual income of energy, in the form of wind and water power, that is not converted into capital, and in the future we may be compelled to have recourse to it again to a still greater extent.

All forms of energy in general use are based on the atom as unit, and may be called "super-atomic." To transform heat, for example, into mechanical power we have harnessed the movements of the molecules of matter ; to produce heat we have utilised the chemical affinities of atoms, and even when electricity has been pressed into the service of man the atom has still remained the fundamental entity. Our experience has been summarised by the great doctrine of the Conservation of Energy.

But now the time has come when scientific research has revealed the existence of a new capital of energy contained in the atom itself, and known as "sub-atomic" energy, in comparison with which the stores of super-atomic energy are merely trivial. Although we cannot draw upon this capital, its discovery has revolutionised our conception of matter.

Whereas the burning of a gramme of coal in air, by means of which $2\frac{2}{3}$ grammes of oxygen are also consumed, evolves about 2,200 calories of heat energy per gramme, more than a million times this amount is evolved by the spontaneous disintegration of a gramme of radium. Sir Oliver Lodge has calculated that the sub-atomic energy in an ordinary stick of blackboard chalk, if only it could be harnessed, is sufficient to raise three hundred million tons of matter through a distance of one foot, or one ton through three hundred million feet, more than twice the distance round the world.

It is probable that in the stars there is going on a transmutation of the elements, more complex ones being built out of the atom of hydrogen, the simplest of all, whilst others are themselves disintegrating, and accompanying it is a liberation of electrical energy. And what is going on spontaneously in the stars has actually been accomplished artificially in the last year or two by Sir Ernest Rutherford in the Cavendish Laboratory at Cambridge. Although, as yet, the total amounts of sub-atomic energy he has liberated have been minute, they are enormous when compared with the quantities of matter affected; but it must be added that there is no evidence to suggest that we shall be able to tap these stores of power for human use in the near future.

During the last few years our conception of the nature of matter has entirely changed; but before we consider it in detail it will be well to summarise the situation briefly. The nineteenth century dispelled the hazy ideas of the alchemists. New elements were continually being discovered, and the more exact investigation became the more likely did it appear that these and those previously known were the ultimate materials of the universe; hence the very name "element," a collection of atoms that cannot be distinguished from each other by any chemical process. More than eighty were known. Mendeléeff had found it possible to arrange a periodic scheme by means of which undiscovered elements could be predicted to fill the blank spaces in the table; subsequent discovery showed how accurately the properties of such elements had been foretold. Later on, Sir William Crookes thought of the evolution of the elements from a fundamental something he called "protyle," a hypothesis originally advanced by Prout in 1815. But with the advent of the twentieth century came the greatest change. From many sides attacks were made on the idea of the mutual independence of the elements, each of which had been supposed to possess precise and exclusive characteristics. It was shown that elements existed in which the atoms were not all exactly alike, although the different specimens of such elements were chemically indistinguishable from one another;

these were named "isotopes" by Professor Soddy. Lead, for example, is one of them. This substance may be obtained in several different ways; to the chemist it is always lead, but its atomic weight depends on the way in which it has been derived.

That there was some intimate connection between the elements was also shown by the expulsion of a particle of helium from many of them, and a particle of hydrogen from some. It is not improbable indeed that the atoms of all the elements are built up from atoms of hydrogen and electrons. Thus the older interpretation of matter, which in its ultimate analysis resolved the universe into the eighty or ninety independent elements, has given place to a monistic, or at most a dualistic, view, and to some extent physics has invaded the realm of metaphysics.

So we come to the fundamental questions, What are the constituents of an atom? What are the electrons? How many are there in the atom? How is the atom built up from them?

The atoms of any particular element are the smallest particles of it that can exist, far too minute for us ever to hope to see. A hundred million of them, placed end to end, might stretch across a penny. They have often been regarded as hard spheres not unlike tiny balls of steel, and in many ways they behave as though they were. They are certainly very difficult to penetrate, and their outer surface alone is touched by any ordinary experiment of a chemical or optical kind. The only particles that can reach their inner parts are those thrown off by the radio-active substances.

Radio-activity has been so well summarised by C. G. Darwin that we can do no better than refer to his description of the phenomenon. It is a series of transformations of a substance through a number of states, in each of which the temporary substance formed has all the characteristics associated with the word "element." The radio-active elements, indeed, differ from the others only in the fact that in addition to their ordinary chemical and physical properties they are also continuously transmuting themselves spontaneously into other elements. During the transformations there are given off three typical kinds of radiation known as the $\alpha$, $\beta$, and $\gamma$ rays respectively.

The $\alpha$ particle is an atom of helium having a charge of positive electricity twice as great as that of an electron, so that it is sometimes regarded as having *two* positive charges each equal to that of an electron, but opposite to it in sign. The latter point of view obviates the necessity of thinking of charges of different magnitudes. The velocity of the particle varies with the radio-element disintegrating, and, in some cases, is greater than 12,000 miles per second, a speed too great to be conceived in the abstract, but which means half-way round the world in one second! One such case, for example, is that of the transient element Radium C′, the average life period of which is only about one-millionth part of a second.

The $\beta$ particle, on the other hand, is an electron, a particle of disembodied electricity, or electricity divorced from matter, of definite and constant negative charge, the unit to which reference is made in the preceding paragraph. The velocity of these particles also varies with the element disintegrating, and in some cases is no less than that of light itself, 186,000 miles per second, or more than seven times round the world in a second. The velocity of the $\beta$ rays from many elements is considerably less than this, varying from 40 to 80 per cent. of it, values that are still enormous.

The $\gamma$ rays are X-rays of shorter wave-length, and therefore greater frequency, than those produced artificially, vibrations of the ether several thousand times shorter than those of light, set up by the movement of electrons in the innermost region of the atom.

The speed of all these rays is so great that it gives them the power of penetrating the atom, and going right through it. Their penetrating power may vary considerably, yet that of one class is quite distinct from that of the others, and by this means the rays were first classified. Thus the most penetrating $\alpha$ ray known is only about twice as powerful as the least penetrating, but the penetrating power of the $\beta$ rays as a whole is about one hundred times that of the $\alpha$ rays as a whole, and that of the $\gamma$ rays in turn is one hundred times that of the $\beta$ rays.

Now as the $\alpha$ and $\beta$ particles penetrate the atom, they will sometimes pass very close indeed to the nucleus or the electrons and thereby be deflected from their course, the $\beta$ particles fairly easily because they are so light. This can be shown by allowing a parallel beam of $\beta$ rays to fall on a thin sheet of a substance, when it will be noticed that the emerging beam is no longer parallel, but scattered.

C. T. R. Wilson has succeeded in photographing the paths of these particles in air and in other gases. Those of the $\alpha$ rays are almost perfectly straight, but with an occasional large deflection, for the $\alpha$ particles are so massive, compared with the electrons, that it requires the cumulative effect of a large number of the latter to produce any appreciable spreading of an $\alpha$ beam, or the action of the nucleus of the atom to deflect an $\alpha$ particle. Experiments based on these deflections have shown that the positive charge of the nucleus of the atom, and therefore, as we shall see, the number of electrons in the atom, is equal to about half the atomic weight of the substance considered.

But what do we mean by this term "atomic weight"? We mean, in effect, the weights of the atoms of the elements, these being different as we pass from element to element. They cannot, of course, be measured in the straightforward way of weighing the atoms singly in turn; they are determined indirectly by methods based on the fundamental facts of chemistry. Dalton showed, many years ago, that when chemical change occurs between two elements it occurs in definite proportions by weight of the two elements. If unit weight of one is taken, then the weight of the other is a definite and fixed amount. If the same elements combine to form other compounds in other proportions, then if unit weight of the first be taken again, the weight of the second will still be some simple multiple or sub-multiple of the first. This indicates that the combination of elements does not occur in a haphazard way, but atom by atom by definite relative weight. So we get what we call the atomic weights.

When they have been found for the different elements, their values are expressed not as very small fractions of a very small weight, such as an ounce or grain or gramme, but simply as numbers on a scale. It must not be forgotten that although these numbers are called "atomic weights," they are not the *actual* weights of the atoms, but are for purposes of comparison only. The standard of comparison is the atomic weight of oxygen, which is chosen as being 16. Uranium, the heaviest element, is then 238, gold is 197, zinc is 65, helium 4, and hydrogen just a little more than 1. So we know at once the comparative weights of the atoms of the elements, and we can easily arrange them in ascending order.

The question was first tackled by Newlands in 1864, but was developed further five years later by Mendeléeff and Meyer independently. When the elements are written down in the proper order of their atomic weights, it is seen that consecutive ones differ from each other in general properties and characteristics in a most abrupt and surprising way, much (to use an analogy given by Professor Soddy) as do the notes in a scale of music. But when several of the elements have been passed, it is found that their general characteristics are reproduced by the next set, in much the same way as the next octave of the musical scale reproduces the general characteristics of the preceding one. When Newlands formulated his law it so happened that the number of elements known was such that this reproduction of characteristics began with the eighth element after the first, and hence he called it the Law of Octaves.

| Group O. | Group I. | Group II. | Group III. | Group IV. | Group V. | Group VI. | Group VII. | Group VIII. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 Helium He. 3·99 | 3 Lithium Li. 6·94 | 4 Beryllium Be. 9·1 | 5 Boron B. 11·0 | 6 Carbon C. 12·00 | 7 Nitrogen N. 14·01 | 8 Oxygen O. 16·00 | 9 Fluorine F. 19·0 | | | |
| 10 Neon Ne. 20·2 | 11 Sodium Na. 23·00 | 12 Magnesium Mg. 24·32 | 13 Aluminium Al. 27·1 | 14 Silicon Si. 28·3 | 15 Phosphorus P. 31·04 | 16 Sulphur S. 32·07 | 17 Chlorine Cl. 35·46 | | | |
| 18 Argon A. 39·88 | 19 Potassium K. 39·10 | 20 Calcium Ca. 40·07 | 21 Scandium Sc. 44·1 | 22 Titanium Ti. 48·1 | 23 Vanadium V. 51·0 | 24 Chromium Cr. 52·0 | 25 Manganese Mu. 54·93 | 26 Iron Fe. 55·84 | 27 Cobalt Co. 58·97 | 28 Nickel Ni. 58·68 |
| | 29 Copper Cu. 63·57 | 30 Zinc Zn. 65·37 | 31 Gallium Ga. 69·9 | 32 Germanium Ge. 72·5 | 33 Arsenic As. 74·96 | 34 Selenium Se. 79·2 | 35 Bromine Br. 79·92 | | | |
| 36 Krypton Kr. 82·92 | 37 Rubidium Rb. 85·45 | 38 Strontium Sr. 87·63 | 39 Yttrium Yt. 89·0 | 40 Zirconium Zr. 90·6 | 41 Niobium Nb. 93·5 | 42 Molybdenum Mo. 96·0 | 43 — | 44 Ruthenium Ru. 101·7 | 45 Rhodium Rh. 102·9 | 46 Palladium Pd. 106·7 |
| | 47 Silver Ag. 107·88 | 48 Cadmium Cd. 112·40 | 49 Indium In. 114·8 | 50 Tin Sn. 119·0 | 51 Antimony Sb. 120·2 | 52 Tellurium Te. 127·5 | 53 Iodine I. 126·92 | | | |
| 54 Xenon Xe. 130·2 | 55 Cæsium Cs. 132·81 | 56 Barium Ba. 137·37 | 57 Lanthanum La. 139·0 | 58 Cerium Ce. 140·25 | 59 Praseodymium Pr. 140·6 | 60 Neodymium Nd. 144·3 | 61 — | | | |
| 62 Samarium Sa. 150·4 | 63 Europium Eu. 152·0 | 64 Gadolinium Gd. 157·3 | 65 Terbium Tb. 159·2 | 66 Dysprosium Dy. 162·5 | 67 Holmium Ho. 163·5 | 68 Erbium Er. 167·7 | | | | |
| 69 Thulium Tm. 168·5 | 70 Ytterbium Yb. 172·0 | 71 Lutecium Lu. 174·0 | 72 — | | 73 Tantalum Ta. 181·5 | 74 Tungsten W. 184·0 | 75 — | 76 Osmium Os. 190·9 | 77 Iridium Ir. 193·1 | 78 Platinum Pt. 195·2 |
| | 79 Gold Au. 197·2 | 80 Mercury Hg. 200·6 | 81 Thallium Tl. 204·0 | 82 Lead Pb. 207·20 | 83 Bismuth Bi. 208·0 | 84 Polonium | 85 — | | | |
| 86 Niton Nt. 222 | 87 — | 88 Radium Ra. 226·0 | 89 Actinium | 90 Thorium Th. 232·12 | 91 Uranium X2 | 92 Uranium U. 238·18 | Placed in no group: 1 Hydrogen H. 1·008 | | | |

But the discovery of the inert gases in the atmosphere since then has added another vertical column (Group 0) to the table, or, to use the same analogy, another note to the scale. In the table (see fig.) the symbol and the atomic weight are written underneath the element, whilst above them is the atomic number, the most important constant of the element, and one which will be considered later.

But the Periodic Table is somewhat more difficult than would appear from this statement. In three cases pairs of elements are arranged in the inverse order of their atomic weights, argon before potassium, cobalt before nickel, and tellurium before iodine, this arrangement being necessary to avoid the breaking up of similar families, and is due, as was recently pointed out by Aston in the *Journal of the Chemical Society*, simply to the existence of isotopes.

The law holds very well indeed for the first two horizontal lines and half-way through the third, but then come ten elements from Vanadium to Germanium before the characteristics of the preceding ones fully reappear again ; these may best be regarded as being interpolated into the table. Then we go along normally from Arsenic to Zirconium through the full period of eight, before we find ten again interpolated from Niobium to Tin. But after the fifty-sixth element, Barium, the table completely and utterly breaks down, and we have a group of sixteen, known as the " Rare-earth metals," all so very much alike that the separation of one from another is one of the most difficult tasks the chemist has to face. These are merely written continuously in the table without attempting to fit them into the Groups.

Following them is a group of ten from Tantalum to Lead, and then the table runs on normally to the end. The thirty elements in the table that we have regarded as being interpolated are well-defined metals and differ among themselves less markedly from member to member along the horizontal lines than do the other elements in other parts of the table. To make them fit properly we make a ninth group, known as No. VIII (since there is also a No. 0), and this contains three sets of three each.

The resemblances between the members of the groups may be brought out still more clearly by dividing some of the latter into two sub-groups. Thus, for example, in Group I we have the so-called alkali metals in one column and copper, silver, and gold in the other. The individual members of each sub-group are most closely connected with the other individuals in the same vertical column, but the sub-groups are themselves connected by virtue of compounds that may be formed from the substances in them.

It will be noticed that some of the places in the table have been left blank. As the result of Mosely's investigation of the characteristic X-ray spectra of the elements, it can now be said that there are only ninety-two elements between hydrogen and uranium, both inclusive, and as eighty-six are already known there are still six left to be discovered. These will fill the blank spaces.

With this knowledge of the Periodic Table, to which we shall have to refer again in a moment, let us go back to the experiments on the $\alpha$ and $\beta$ particles. In the course of the investigations it was observed that whilst most of the $\alpha$ particles went straight through the atom there were a few, of the order of one in many thousands, that were thrown entirely off their line of motion, much as are the $\beta$ particles. Now the $\alpha$ particle is so massive compared with the electrons that a considerable force is required to deflect it in this way, and this presupposes another body of large mass and charge. On this as basis there has been built the theory of the structure of the atom, the most important features of which are now well established.

At the centre of the atom is a core or nucleus, which may contain charges of both positive and negative electricity, but on which the positive ones always predominate in such a way that the nucleus is positively charged to the extent of about one unit for every two units of atomic mass. Around it, and spaced out to occupy the rest of the atom, are the electrons, one for each surplus positive charge on the nucleus, so that the atom as a whole is electrically neutral. The electrons may revolve round the nucleus much as do the planets of the solar system round the sun, but whereas in the solar system the sun is a very great deal larger than any of the planets, in the atom the nucleus is no bigger, but probably smaller, than the electrons, which are themselves exceedingly minute compared with the diameter of the atom, something of the order of about one-hundred-thousandth part of it, a somewhat similar proportion to that of the earth compared with the whole of the solar system. Yet practically the whole of the mass of the atom is concentrated on this tiny nucleus !

We shall see in a moment that there can never be more than ninety-two electrons spaced out around the central core of the atom, and since they are all so very small there is brought about the strange result that practically the whole of the atom is empty space.

Dr. A. S. Russell has given an illustration which will help us to realise what this means. Consider an atom so magnified as to appear superficially as large as Ireland. On such a scale the nucleus, situated at Athlone, the centre of Ireland, would be a ball of 8 feet radius. In other parts of Ireland, at various distances from Athlone to the coast, would be other balls of much the same radius, standing for the electrons. There might be only one of these, or there might be as many as ninety-two, but in any case these and the nucleus would be the whole of the atom.

The number of electrons round the nucleus varies from element to element and increases by unity for each place in the Periodic Table. This number is the most important constant of the element and is known as its Atomic Number. Not only does it tell us how many satellite-electrons there are in the particular atom, but also, as we have seen, how many surplus positive charges there are on the nucleus. On it depend the chemical and physical properties of the element, so that if, by any means, the atomic number is changed, as, for example, by the expulsion of an electron, then the chemical and physical properties are changed, which means that a different element is formed and transmutation is effected.

The atomic number of hydrogen is 1, of helium 2, of lithium 3, and so on. Further up the scale we find tin with atomic number 50, and so we know that on the nucleus of the atom of tin there are fifty surplus positive charges and that round it are fifty electrons. And similarly for all the elements, the greatest number of electrons, ninety-two, being in the atom of uranium.

So the mass of the atom varies with the number of electrons it contains. But the electrons do not constitute the mass; this is found in the nuclear positive charges to which they correspond. For since an electron, or $\beta$ particle, weighs only one-eighteen-hundredth part of the lightest atom of all, that of hydrogen, even ninety-two of them make no appreciable difference to the total mass. It may be somewhat difficult to appreciate the significance of the word "mass" when applied to an electron, for an electron, as we have seen, is electricity divorced from matter, and we have always hitherto associated mass with matter and with matter only. But we must remember that an electron cannot be moved from rest, nor be brought to rest if moving, without an expenditure of energy, and it is in this sense that we must regard it as having inertia or mass.

If it were possible to alter the number of electrons in an atom, the immediate consequence would be the transmutation of the elements. Take the case of radium. Its atomic number is 88, so that its nucleus carries 88 surplus positive charges and is surrounded by 88 electrons. Now radium disintegrates spontaneously and expels an $\alpha$ particle, which is an atom of helium carrying two positive charges. Its own nucleus, therefore, is left with eighty-six positive charges, so that it is no longer radium, but a new element niton, or radium emanation, of which the atomic number is 86.

If, to take an imaginary case, mercury, with atomic number 80, expelled an $\alpha$ particle, it would lose two positive charges and become the 78th element, platinum. If it lost a $\beta$ particle as well, it would lose two positive charges and one negative, that is, one positive on the whole, and so it would retain 79 surplus positive charges on the nucleus and thus become gold. But if the mercury lost one $\beta$ particle only, and no $\alpha$, the surplus *positive* charges on the nucleus would become one more, viz. 81, and thallium would be produced. If it lost two negative charges, $\beta$ particles, it would transmute itself to lead, and so on for other combinations.

But when we ask how this expulsion of particles is to be brought about, we are face to face with the supreme difficulty of the problem. In the radio-active elements the change is spontaneous, and we are quite unable to accelerate or retard it, or to influence it in any way. The particles are expelled, the element is transmuted, and energy is liberated at a perfectly constant rate. For the other elements we have to find some projectile that is very tiny, and yet moving with an incredible velocity, and with it bombard the atom and break up the nucleus. The only projectiles that fulfil these conditions are the $\alpha$ and $\beta$ particles.

Sir Ernest Rutherford has used them to bombard the atoms of nitrogen, and has found that from a very small percentage of them atoms of hydrogen are produced.

It remains to ask what light this theory of the structure of the atom can throw on the vertical groups in the Periodic Table, a subject amplified in the Presidential Address to the British Association last year. We have already seen that the positive charges, or protons, of the atom are concentrated on the nucleus at the centre, and the electrons are around it. Mathematical investigation has shown that this arrangement is quite possible if the electrons are on a sphere and not too close together. The mutual forces of repulsion between them will prevent overcrowding, and Sir J. J. Thomson has proved that when there are more than a certain number of electrons on the sphere the force of attraction exerted by the positive nucleus is not sufficient to maintain stable equilibrium, so that a new arrangement is formed with different layers of electrons on concentric spheres. The number of electrons on the outer sphere depends upon the law of force between the nucleus and the electrons and between the electrons themselves, and Sir J. J. Thomson has shown that if this law of force is of a simple type then the number of electrons that can exist in a layer is eight. Professor Langmuir, who assumes as a working hypothesis that the electrons are in static equilibrium and not in continual orbital movement, believes that the electrons arrange themselves on successive sheaths with 2 on the inmost, 8 on the next, then 8 again, followed by 18, 18, and 32.

Lithium, the first element in Group I, but third in the whole list, is supposed to have one electron in its outer layer, the first two electrons being on an inner layer. The next element, beryllium, is supposed to have two electrons in its outer layer, boron three, carbon four, nitrogen five, oxygen six, fluorine seven, and neon eight. This is the maximum number, and when the next element is reached the additional electron has to begin a new outer sphere, with the result that sodium is like lithium in having one outer free electron. Thus the series starts over again, so that those properties of the elements that depend on the number of electrons in the outer layer of their atoms must recur periodically, and this is just the fact that was expressed more than fifty years ago by Mendeléeff's Periodic Law.

# DIFFUSION IN DEFORMED GELS

By EMIL HATSCHEK, F.Inst.P.

Elastic gels, *e.g.* gelatin gels, are optically isotropic when free from strain and exhibit accidental birefringence when deformed. This behaviour has been known for a considerable time ; as the refractive indices of the ordinary and extraordinary ray differ very slightly, specimens of some thickness can be examined in polarised light, and this method has been used in several investigations on the elastic properties of gelatin gels.[1] Reiger employed it for determining the relaxation time, with a view to testing Maxwell's relation between modulus, viscosity, and relaxation time, and found the latter to be of the order of minutes at 29° C.—a temperature which is very near the " melting point " of gels with the concentrations used by him.

No other property of gels has been studied from this point of view. One such property, which is of considerable importance in the economy of nature, is the permeability of gels to substances in true solution in the liquid constituent of the gel. The diffusion of true solutes into gels has been studied by Thomas Graham and several later investigators, but the question whether elastic gels *under stress become anisotropic or remain isotropic as regards diffusion velocity* does not appear to have been raised. Assuming gels to be heterogeneous systems, anisotropy seems at least possible, and the experimental investigation of the question appeared to me of interest from two reasons : on the one hand, because the results might throw some light on this very question of gel structure, and on the other, because a considerable number of processes in organisms, which depend on diffusion, take place in gel-like media subject to continuous or periodic deformations.

Reference has been made above to Reiger's results, viz. complete relaxation in 10 to 40 minutes. If these held good at ordinary temperatures, investigation of the diffusion velocity would have been hopeless, as diffusion experiments in gels of

[1] E. Hatschek, " The Properties of Elastic Gels." General Discussion on " The Physics and Chemistry of Colloids, etc.," October 25, 1920. H.M. Stationery Office.

such concentrations as can conveniently be handled must be continued for hours or even days. I had, however, shown previously[1] that optical anisotropy persists in deformed gels kept at ordinary temperature (10° to 15° C.) for many days after the complete disappearance of stress, which appeared to justify even prolonged experiments.

The deformation employed in the first instance was the simplest conceivable. A rectangular prism of gelatin gel was compressed between two parallel plates, in such a manner that it could expand freely in the two directions at right angles to the axis of compression, to 80 or 70 per cent. of its original height. Into one of the faces parallel to the direction of compression a solution diffused through a small circular opening. The diffusion zone in an isotropic medium is (very approximately) a hemisphere and its intersection with the gel surface is the equator of the former. Assuming the gel to become anisotropic, the diffusion velocities in the direction of maximum compression and in that at right angles to it—in which the gel undergoes maximum elongation—would be different, in which case the intersection of the diffusion zone with the surface would no longer be a circle.

Simple as this arrangement is in principle, considerable difficulties were encountered in realising it experimentally. The first was the choice of a suitable diffusing solution. As comparative measurements of the diffusion zone were required, a sharp boundary was necessary, which naturally could not be secured by using, *e.g.*, a coloured solution only, as this produces a gradient to zero concentration. It is therefore essential to produce *a reaction* between the diffusing solution and some sort of indicator contained in the gel, which gives a sharp line of demarcation. Although at first sight the choice of suitable solutions and indicators seems almost unlimited, it proved in practice to be very narrow if all sources of error were to be avoided. Thus any solution having a lyotropic action was at once ruled out, as it would distort the results completely. If, to give a striking example, a very dilute acid is allowed to diffuse into gelatin gel (oxalic acid gives a sharp boundary even without indicator owing to the presence of calcium salts in all gelatins), the diffusion zone *swells* markedly and its modulus decreases correspondingly. The diffusion zone therefore yields to the compression more than the surrounding gel and becomes elliptical. No valid conclusions regarding the diffusion velocity can, however, be drawn from this—rather tempting—result : this can easily be demonstrated by allowing acid to diffuse into an *uncompressed* prism and compressing it subsequently. The diffusion zone becomes an ellipse, the

[1] Ibid.

axial ratio of which, however, is *not* the ratio of compression to transverse extension, as it would be if the gel remained uniform throughout.

Solutions which are reduced by the gelatin itself, like silver nitrate or potassium permanganate, proved unsuitable for similar reasons, although they also produced sharp boundaries. The gel in the reaction zone is incidentally altered to such an extent that its modulus differs widely from that of the surrounding material, so that the results are again spurious.

After numerous experiments, detailed enumeration of which is unnecessary, the following arrangement proved completely satisfactory: a 0·5 to 1·0 per cent. solution of potassium chromate diffuses into a gel containing 0·1 per cent. of lead nitrate or acetate. The lead chromate formed by the reaction is highly disperse, does not precipitate in Liesegang rings, and gives an exceedingly sharp boundary. Careful examination failed to show any swelling under the chromate solution. Purification of the gelatin—which lowers its elastic modulus to an undesirable extent—is unnecessary, as any lead salts possibly formed, such as carbonate or sulphate, are more soluble than the lead chromate and accordingly react with the potassium chromate solution. With the concentrations stated above diffusion zones which can be measured accurately are obtained within four to eight hours, according to the gelatin content of the gel; if necessary, the experiments can be extended for considerably longer periods, as the lead salts appear to have a marked antiseptic effect, so that specimens can be kept at room temperature in an atmosphere saturated with water vapour for five to eight days without showing mould or signs of putrefaction.

The second difficulty was that of letting diffusion take place through an opening of strictly defined size. In the initial experiments, masks of lead, tin, silver, and rubber foil were employed, into which a circular hole of 2–3 mm. diameter had been punched. These masks were squeezed on the gel surface so as to secure good contact, and the chromate solution was then placed on the opening with a small pipette. With these opaque masks it was impossible from the outset to be sure that perfect contact round the edge of the opening had been secured; even if this (as far as could be judged from examination of the specimen at the end of the experiment) had been the case at first, the solution frequently crept under the mask. Perfectly satisfactory results were finally obtained with glass masks consisting of halves (1 in. × $1\frac{1}{2}$ in.) of thin microscope slides, with a drilled hole 1·1 mm. diameter in the centre. With these transparent masks the absence of air bubbles immediately showed whether complete contact with the gel surface had been made; when this was the case, they never detached themselves in the course of the experiment. Discrepancies in the results obtained with the glass masks in the first experiments were found to be due to a small air bubble adhering obstinately to the wall of the hole; a difficulty which, once diagnosed, was easily overcome.

If two preparations, *e.g.* one compressed and the other free from strain, are to be compared, it is of course necessary to employ not only orifices of the same size, but also equal volumes of solution, so as to keep the diffusion "head" the same. For this purpose rubber rings were cemented on the slides described, which held 0·5 c.c. of liquid.

The prisms to be examined were cast in a brass tube of square cross-section, corked at one end. They were left in

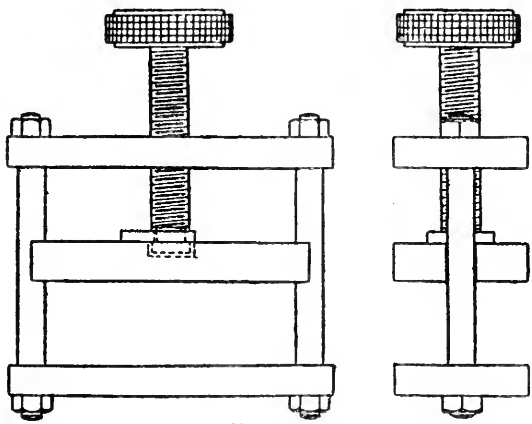

FIG. 1.

the mould for at least twenty-four hours, so as to attain the maximum modulus, and were then removed by dipping the mould into hot water for a short time and withdrawing the cork. To harden the surface again, they were then dipped in cold water for a few seconds, dried rapidly with filter-paper, and finally cut into pieces about 50 mm. long. The cross-section of the prisms obtained in this manner was very uniformly 28 mm. square.

The test pieces were always used immediately after preparation. They were compressed in the precision clamps illustrated in Fig. 1, made of gun-metal, with the exception of the screw spindle, and of ample rigidity not to be deformed by the very low stresses. The distance between the fixed and movable jaw was measured by micrometer callipers to 0·1 mm. The internal faces were coated with vaseline or liquid paraffin before clamping the test piece: this precaution was found to be necessary on examining test pieces in polarised light, when they were seen to adhere strongly to the jaws in places and to be deformed in a highly irregular manner. Greasing the faces prevents this adhesion and allows the test piece to expand regularly in the two directions at right angles to the axis of the screw spindle. According to the gelatin concentration the prisms were compressed to 24, 22, or 20 mm., the initial dimension being 28 mm. in all instances. Two test pieces clamped in this fashion, and one control piece left quite free (all three cut from the same piece of gel), were placed in a metal box lined with moist filter-paper and were then covered with the masks and the chromate solution. The progress of diffusion, *i.e.* the formation of lead chromate, is easily observed through the glass mask; when the zone of chromate had attained a sufficient size, the solution was removed with a capillary pipette and filter-paper, the mask detached and the diameter of the diffusion zone measured to 0·1 mm.

The experimental arrangements have been described in detail which may seem exaggerated unless it be taken into account that all the precautions were proved necessary by painful experience and that the accuracy of the results depends on their complete and rigid observance.

The outcome of numerous experiments was somewhat unexpected—at least by me. Repeated investigation of 6, 8, 10, and 12 per cent. gelatin gels showed that *the diffusion zones in the stressed prisms were perfectly circular in all cases: moreover, the diameter of the diffusion zone was the same in a compressed as in an uncompressed test piece of the same gel.* In other words, the gel remains *isotropic for diffusion* under stress and the diffusion velocity is the same in the deformed and in the unstressed gel.

One set of experiments out of a large number performed will be sufficient to illustrate the point. The gel was: 6 gm. of Cox's powdered gelatin in 100 c.c. of water with 0·1 gm. of lead acetate.

| | Prism I. | Prism II. | Prism III. |
|---|---|---|---|
| Compressed from 28 mm. to . | 20·0 | 22·0 | 28·0 (free) |
| Diameter of diffusion zone after 4 hrs. 30 mins. . . | 12·8 | 12·8 | 12·8 |

If the prisms are released at the end of the experiment—the diameter of the diffusion zone having, of course, been measured before release—they expand again, but do not, notwithstanding the short duration of the stress, return to their original dimensions. Owing to this expansion the circular diffusion zone becomes elliptical, as will be gathered from the following figures, which refer to the set previously quoted :

| | Prism I. | Prism II. |
|---|---|---|
| Original height 28 mm. : | | |
| Height after release . . . | 24·2 | 25·0 |
| Major axis of diffusion zone . . | 15·0 | 15·0 |
| Minor axis of diffusion zone . . | 11·5 | 12·1 |

If, therefore, diffusion takes place during temporary deformation the diffusion zone may, after removal of the stress, simulate a marked anisotropy, a point which may possibly be of histological interest. Even fairly small and transitory deformations may leave a permanent record in this fashion.

Concurrently with the quantitative experiments just described a number of qualitative ones were carried out, in which a reaction producing Liesegang stratifications was made to proceed in deformed gels. The conditions with this arrangement are too complicated for quantitative investigation, as the deformation may conceivably affect other factors besides

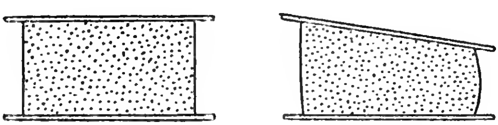
A B

FIG. 2.

the diffusion velocity. The test pieces in these experiments were short right cylinders : the parallel ends were closed by glass plates, put on warm, so as to confine diffusion to the peripheral surface and eliminate the well-known complications when diffusion into a gel takes place through two faces meeting in a sharp edge. The cylinders were then deformed by a simple device so that the originally rectangular axial section (Fig. 2A) became approximately trapezoidal (Fig. 2B), care being taken to keep the one side—the left in the illustration—as far as possible its original length. The compression in the principal axial section accordingly increases in—probably—linear ratio from left to right. The cylinders thus deformed were completely submerged in the reacting solution, the progress of diffusion being readily observed through the upper glass plate. Towards the end of the experiment gradually increasing quantities of formaldehyde were added to the solution so as to harden the test pieces completely before they were released and cut through. From the hardened gelatin the glass plates detach themselves quite easily.

The reaction employed was that between tribasic sodium phosphate (in the gelatin) and various calcium salts, which gives extremely fine and occasionally very complicated periodic deposits of tricalcium phosphate.[1] Sections through two specimens are illustrated in Fig. 3. This is a reproduction of an actual photograph, on which the zones of clear gel between the bands have been coloured black; the white spaces are the precipitate. The breaks in some of the latter are a curious and so far unexplained feature of the particular reaction. Apart from them, the two halves of the preparation —which was cut in the axial plane of maximum slope—show slight asymmetry, but this is hardly sufficient to permit definite conclusions. In view of the quantitative results described

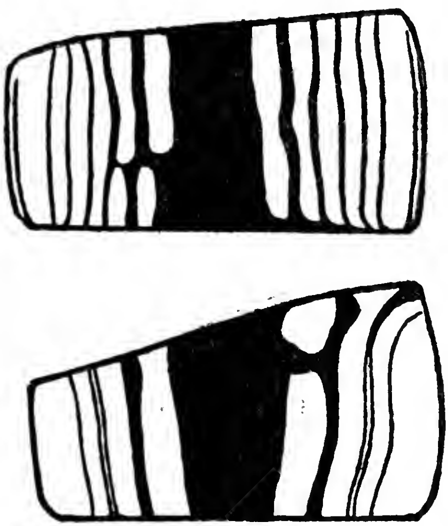

FIG. 3

above, it appears at least improbable that the diffusion velocity varies with the varying degree of compression, and any anomalies in the stratifications would therefore have to be ascribed to the effect of deformation on one or more of the—numerous and in part obscure—factors which influence it under normal conditions.

An experiment similar to those in gelatin cylinders has been described by W. A. Richardson in a paper to which my attention was drawn only quite recently (" The Relative Age of Concretions," *Geol. Mag.*, lviii, p. 121, 1921). It was directed to ascertaining the effect of unequal stresses on the formation of the silver chromate bands of the original Liesegang reaction,

[1] E. Hatschek, "Eine Reihe von abnormen Liesegang'schen Schichtungen," *Koll.-Zeitschr.*, xxvii, 225, 1920.

and the method of stressing is best described in the author's own words: "Pour a bichromate gel into a cardboard tray to a depth of about $\frac{1}{8}$ in. Support a glass, or xylonite, plate provided with a small central hole, in contact with the surface of the gel until the latter has completely set. The transparent plate must fit the tray *exactly*. When setting is complete, cut away two opposite sides of the tray, supporting the other pair by wooden blocks. Press the plate on to the surface of the gel and apply weights. The gel is now free to move in one direction, but hindered in the other. It is therefore compressed against the remaining sides of the tray. Now place a drop of strong silver nitrate over the central hole and leave in a damp atmosphere to diffuse.

"In all cases where differential straining of the gel was successful, the diffusing silver nitrate reached an elliptical boundary."

No independent criterion regarding the strains in the gel appears to have been applied: examination in polarised light would have shown the distribution of strain unambiguously, but is not mentioned and could not have been used with a cardboard tray as container. The strain must have been of a complicated character, as the gel adhered to the cardboard, and also very probably to the glass plate, at least at first; as far as I know, gelatin gel does not adhere to xylonite without some special precautions. Assuming the gel to adhere to both the tray and the cover plate, compression would set up a complicated internal strain and of course bulging round the edges; there would also be a strong tendency for the gel to detach itself from the glass and to shift in the direction in which it is free to escape, viz. where the opposite sides of the tray have been removed. The tendency of the gel to detach itself from the glass is much increased by the formation in it of a dense precipitate and by the well-known contraction which takes place when the concentrated silver nitrate diffuses into a fairly dilute gelatin gel. In view of my own results, it therefore appears probable that the ellipticity of the reaction zone is due, not to differences in the diffusion velocity, but to a gradual yielding of the gel which mimics this effect. In the experiments with cylinders I have found it one of the greatest difficulties to prevent the upper plate from detaching itself as the reaction progresses, and the consequent spurious differences in the reaction zones at opposite ends of the same diameter.

From the results obtained so far with sufficient precautions it is not possible to do more than draw a negative conclusion as regards the problem of gel structure: the conclusion that those elements which on deformation give rise to optical anisotropy and to elasticity of shear are either without influence on the diffusion of true solutes, or else arrange themselves under stress in such a manner that the passages available for diffusion retain equal cross-sections in all azimuths with the axis of compression. It is hardly possible to discuss this aspect of the question until we have a profounder insight into the origin of accidental birefringence in strained elastic gels, and more particularly into the persistence of anisotropy long after the removal of stress to which reference has been made (*loc. cit.*, 1).

The deformations obtainable in gelatin gels are comparatively slight, especially if it is desired to keep them within the elastic limit even for short periods of stress. Several attempts have therefore been made to carry out similar experiments in gels of vulcanised indiarubber. Such gels, obtained by vulcanising rubber sols with various reagents, have been available for some time and permit considerable deformations. The experimental difficulties, however, caused partly by the volatility of the dispersion medium and partly by the choice of a reaction giving a sharp boundary, are so great that no conclusive results have been obtained so far.

# THE LIFE-HISTORY OF THE COMMON OR FRESHWATER EEL

By C. TATE REGAN, M.A., F.R.S.

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The Common or Freshwater Eel (*Anguilla anguilla* or *A. vulgaris*) has a remarkable geographical distribution, occurring on the coasts and in the rivers of Western Europe and the countries bordering the Mediterranean, ranging from Iceland and Northern Norway southwards to the Canaries and Morocco, and from the Azores eastward to Palestine. This distribution is anomalous and at first sight inexplicable; one can hardly believe that it is limited by temperature, seeing that the same species is found in Iceland and in the Nile; nor can it be a question of food, for the Eel is somewhat of a scavenger, and eats all kinds of animal food. In fresh water eels are found not only in lakes and rivers, but in small streams and isolated ponds; they are abundant in estuaries and also in harbours and other inlets where the water is quite salt; indeed, at the great eel-farm at Comacchio the water in the lagoons has, towards the end of the summer, a salinity higher than that of the Adriatic. Finally, the Eel is not represented by a related species either in the Arctic Ocean, the Black Sea and its tributaries, or West Africa south of Morocco. One may then ask the question why this species, which lives in such a variety of conditions, has not a much wider range. The answer has been supplied by Dr. Johannes Schmidt, of Copenhagen, whose researches on the life-history of the Eel, begun in 1904 and now practically concluded, are summarised in an important paper recently issued by the Royal Society (*Phil. Trans. B.*, ccxi, pp. 179–208, pls. 17 and 18, April 1922).

Twenty-five years ago all we knew of the breeding of the Eel was that in the autumn full-grown eels moved down from the rivers and lakes to the sea, and that in the spring the elvers, or young eels about 2½ inches long, appeared on the coasts and made their way into the rivers, in some places in such swarms as to form the object of an industry. It was naturally supposed that these elvers were the progeny of the eels which had gone down to the sea in the preceding autumn, and that the breeding places were in the sea not far from the mouths of the rivers. In 1896 came the discovery by Grassi and Calandruccio that a little fish named *Leptocephalus brevirostris*, then known only from the Straits of Messina, is the larva of the Common Eel; this they demonstrated by capturing a series of transitional forms, showing the transformation of the transparent leaf-shaped *Leptocephalus* into the pigmented cylindrical elver (*cf.* Fig. 1). The Italian naturalists concluded that the Eel bred in deep water near the coast and that the larvæ lived in the depths, but in the Straits of Messina were brought to the surface by the peculiar currents, and so were captured there and nowhere else. This hypothesis was perhaps reasonable at the time, but, as we shall see, it was far from the truth.

In 1904 Dr. Schmidt was on board the Danish research ship *Thor*, engaged in investigations in the Iceland and Faroe waters, when a specimen of *Leptocephalus brevirostris* was captured at the surface. This clue was followed up, and in 1905 and 1906 cruises were made in the spring and summer by the *Thor* in the Atlantic west of Europe, and large numbers of eel-larvæ were captured, all in the upper layers of the water; the larvæ caught in spring and early summer were full-grown, about three inches long, but the majority of those taken in August and September had begun the metamorphosis. In succeeding years Schmidt took the *Thor* into the Mediterranean for winter and summer cruises, the results of which were as follows: no eel-larvæ were taken in the Eastern Mediterranean, a large number of full-grown or nearly full-grown larvæ and metamorphosing stages were captured at or near the surface in the Western Mediterranean, and no early larvæ were found. This led to the conclusion that the Eel did not breed in the Mediterranean at all, but that all the eels of the Mediterranean countries—as well as those of Western Europe—resorted to the Atlantic to breed, and that the Straits of Messina, instead of being the breeding ground of the Eel, was in the Mediterranean the farthest away from the breeding ground of any places where eel-larvæ could be caught. This conclusion, based on the distribution of the larvæ, seemed so extraordinary that Schmidt tested it by an elaborate statistical investigation; in large samples of eels from Iceland, Denmark, England, the Azores, and Italy the number of vertebræ was counted, and it was found that in each sample the numbers when plotted gave a normal curve with a mean of 114·7, the range being from 111 or 112 to 118 or 119. This identity in the number of vertebræ in eels from such widely separated localities made it clear that there were no local races of the Eel, and suggested that it had only one breeding area. The correctness of this view was

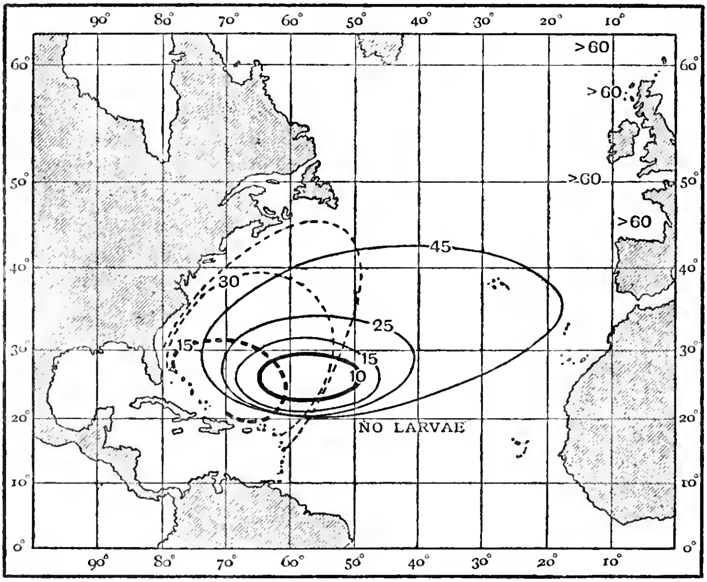
Fig. 1.—Metamorphosis of Eel Larvæ (*Anguilla vulgaris*).

The top specimen is a full grown larva before metamorphosis, the two lower ones are elvers. Atlantic west of British Isles; "Thor" 1906; the elvers from Danish waters. Slightly reduced (from Schmidt).

further demonstrated by a similar analysis of the Viviparous Blenny (*Zoarces viviparus*) a fish not unlike the Eel in form and in habits, but viviparous and therefore not likely to wander much; it was found that there were great differences in the number of vertebræ in *Zoarces* populations from different areas.

So far only full-grown or nearly full-grown eel larvæ (60 to 90 mm. long) were known, and in 1909 Schmidt could say only that it was probable that the breeding grounds of the Eel were situated out in the ocean far from the coasts. In 1910 he found two small larvæ, 41 and 53 mm. long, in the collection of the Copenhagen Museum, the smaller taken near Madeira, the larger in 30° N., 32° W. In the same year Dr. Hjort, in the *Michael Sars*, captured 21 larvæ of 41 to 60 mm. south and west of the Azores. Schmidt now perceived that the only way to find the breeding grounds of the Eel was to make a survey of the distribution and density of the various sizes of the larvæ, and on this work he has been engaged ever since. Good work was done by various Danish vessels sailing to the West Indies, which made occasional short hauls with a pelagic net; but the most important results were obtained in voyages across the Atlantic made by Schmidt in specially equipped vessels, in 1913 the *Margrethe*, which was, unfortunately, wrecked in the West Indies, and since the war the *Dana*. Thousands of larvæ of the Common Eel have been obtained, of all sizes from 5 mm. to 90 mm. long, the smallest still having a remnant of the yolk-sac, and by taking into consideration the size, and the date and place of capture of these larvæ, Schmidt has been able to demonstrate the position of the breeding grounds and the history of the larvæ from the time it hatches until it becomes an elver.

On the accompanying chart (Fig. 2) the continuous curved lines show the limits of occurrence of the larvæ; that marked 10 embraces an area between about 22° and 30° N. and 48° and 65° W.; this area must include the breeding places of the Eel, for within it larvæ less than 10 mm. long have been captured in large numbers, but never outside it. The other curves have been numbered in the same way, *i.e.* larvæ less than 25 mm. in length have been found only inside the 25 curve, etc., and they show how the growing larvæ move northwards and eastwards across the Atlantic. It will be seen that on the chart are some curved dotted lines, indicating the size and distribution of the larvæ of the American Eel (*A. chrysypa* or *rostrata*), a species which differs from the European Eel mainly in the fewer vertebræ (104 to 111 instead of 111 to 119), a character which was used by Schmidt to distinguish the larvæ, the myomeres being counted. It had always been supposed that the breeding area of the European Eel, wherever it might be, would be well to the east of that of the American Eel, and that the larvæ of the two species would not be found in the same waters. Schmidt was therefore greatly puzzled when he began, in the Western Atlantic, to take larvæ of both species in the same hauls, and it is indeed surprising that although all the eels of Bermuda belong to the American species hosts of larvæ of the European Eel occur in the waters round that island. Seeing that the larvæ occur together in the Western Atlantic, why has Europe




Emery Walker Ltd sc.

Fig. 2.—European Eel (*Anguilla vulgaris*) and American Eel (*Anguilla rostrata*).

Breeding areas and distribution of larvæ shown by curves (dotted for the American. continuous for the European species). The heavily drawn innermost curves embrace the breeding areas of the two species. The curves also show limits of occurrence—*i.e.* specimens less than 25 mm. in length have been found only inside the 25 mm. curve, etc. (from *Phil. Trans. R. Society*).

one species of Eel and America another? The answer to this question was found to be as follows: In the American Eel the pelagic larval stage ends in about a year, consequently the larvæ have not time to make the journey to Europe, and any that move eastwards will change into elvers in the middle of the Atlantic. The European Eel takes three times as long over its larval development, so that its larvæ are far away from America when the time comes for them to change into elvers, and any that move to the west or north-west will reach the American coast as small larvæ. This different duration of the pelagic larval stage, with the fact that the centre of production of the American Eel is farther south and west than that of the European species, accounts for the distribution of the two forms. We can now understand the curious geographical distribution of our Common Eel ; it inhabits those countries on whose coasts the larvæ, moving from the Western Atlantic generally in the direction of the Gulf Stream, arrive at the time when they are ready to change into elvers, and those farther regions, *e.g.* the North Sea, Baltic and Eastern Mediterranean areas, to which the elvers make their way. At the time of writing Schmidt is in the Western Atlantic, where he has been trying to capture the breeding eels, the only thing needed to complete his investigation, except an explanation of the reason why the Common Eel resorts to this particular area to breed. This may be forthcoming when the depth at which it breeds is known, and the temperature, salinity, etc., of the water at that depth can be compared with those of other areas.

Having given the above summary of the progress of Schmidt's researches we may now give a short account of the life history of the Common Eel. The strongly compressed, transparent larvæ live in the upper strata of the ocean, from the surface down to 100 fathoms ; they are provided with curious long needle-shaped teeth, which are presumably of use in catching the minute pelagic animals on which they probably feed ; they start life in the spring, in the Western Atlantic S.E. of Bermuda, and the general resultant of their movements is that the majority travel north-eastwards with the Gulf Stream, at such a rate that in a little over two years they are in the neighbourhood of the coast of Europe, when they have attained a length of about 3 inches ; these full-grown larvæ cease feeding, lose their teeth, and in the autumn undergo a series of changes, involving a reduction both in depth and length, ending up as cylindrical elvers about 2½ inches long. The elvers are small eels, with a new set of teeth, small and conical, quite unlike the teeth of the larvæ ; they make their appearance on the coasts in the winter or spring, and numbers of them enter the rivers, and may penetrate far inland. The eels feed and grow in fresh water or on the coasts for some years ; the males usually for from 5 to 7 years, during which they attain a length of 12 to 18 inches ; the females usually for a longer period, 7 to 12 years or more, outgrowing the males and not infrequently reaching a length of 3 feet and a weight of 4 or 5 lbs. These growing eels are yellowish or greenish in colour ; they have small eyes, a blunt snout, thick lips and pale, rounded pectoral fins. When the time comes for them to seek their breeding place they cease feeding and change into "silver eels" in which the body has a metallic sheen, the eyes are larger, the snout is sharp, the lips are thin and the pectoral fins are black and pointed. Their flesh is very rich in fat, which is no doubt expended in the development of the genital glands and in their journey across the ocean. How long this journey occupies is not known: possibly eels that leave Britain in the autumn may cross the ocean in time to breed the following spring, but it seems hardly likely that eels from Finland or Egypt could cover the distance in less than a year. At their breeding place the ocean is over 3,000 fathoms deep, but it is improbable that they breed on the bottom or anywhere near it. One thing that we may be sure of is that all the eels die after spawning; no fish which makes a breeding journey of from 2,000 to 4,000 miles can be expected to do so more than once in its life, and we may infer from the analogy of the Sea-lamprey and other fishes which breed only once that the formation of the genital glands entails the degeneration of all the other organs, rendering recovery after breeding impossible.

It will be seen that this remarkable life-history may be divided into four main stages:—

1. The pelagic larval stage, a period of active growth and passive migration.
2. The transformation into the elver, or young eel.
3. Growth of the eel.
4. Change into the silver eel, and breeding migration, ending in death after breeding.

Schmidt's work has been characterised by extraordinary persistence and insight, and it is certainly no mean contribution to the advance of science to have made clear this unique life-history. Moreover, the *Zoarces* investigation, undertaken as a check on his conclusions from statistical data in *Anguilla*, proved so full of interest that it has been continued and extended, and promises to be of the utmost importance in helping to solve the problem of the origin of local races. Finally, in the voyages made under Schmidt's leadership it was not only larvæ of *Anguilla* that were caught, but a host of pelagic organisms of all kinds. These have been preserved for study, with full data, and already several volumes have appeared, giving some of the hydrographical and biological results of the voyages of the *Thor*, and marking a large advance in knowledge of life in the sea and the conditions that determine its distribution.

# ARCHITECTURAL ACOUSTICS

By G. A. SUTHERLAND, M.A.

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THE subject of the acoustics of public buildings is one of great importance to the community, and merits the attention both of the physicist and of the architect. In the past, at any rate in this country, it seems to have received little consideration from either, and the punishment of having a large number of halls which are acoustic horrors fits the crime of refusing to investigate the problem or to make use of the information made available by the work of others.

The conclusions in earlier books on the subject are for the most part not based on scientific theory or experiment. Some of the principles laid down are right, but others are so evidently arbitrary that all must be subjected to careful scrutiny before any can be accepted as having adequate foundation.

A case in point is the small manual of T. Roger Smith (1),[1] first published in 1876, with a second edition, differing only very slightly from the first, in 1895. This appears to be the most recent work on the subject published in England, and refers to the question as one which is confessedly obscure and has been but little studied.

The book has merits. The author emphasises the value of using heavy absorbent materials not only to prevent echoes, but also to remedy excessive reverberation, and he appraises the stretching of wires at its true value. But some of his rules appear to be quite arbitrary and no explanation of their basis is attempted, while others are based on an incomplete understanding of the mechanism of sound propagation. Thus the acoustic excellence of the lecture theatre at the Royal Institution is attributed firstly to the fact that its height, depth, and breadth are in the simple ratios of 2, 3, and 4. No reason is adduced to show why such a simple relation should favour good acoustics, and the slight discrepancies from these ratios in the actual dimensions might equally well be responsible. Further, the theatre is so much broken up by seats and the gallery that it is very difficult to assign any meaning at all to

[1] The numbers refer to a list of original papers, etc., at the end of the article.

its "height" and "depth." The only suspicious feature in the theatre is said to be the sky-light, and the author seems to think that this just misses having a serious effect because it is circular and not square in plan, a proposition not easy to justify.

The problem of designing an auditorium with satisfactory acoustic properties requires for its complete solution two distinct lines of investigation. In the first place, it is necessary to determine quantitatively the physical conditions on which loudness, reverberation, resonance, and allied phenomena depend. And, secondly, the intensity which each of these should have to produce conditions satisfactory for distinct audition of speech and of music in its various forms must be settled.

The first of these is a purely physical question, which must be capable of scientific experimental investigation, and its conclusions can be disputed only on scientific grounds; the second is a matter of judgment and taste, and its conclusions are convincing in proportion to the weight and unanimity of the authority in which they find their source.

The question as to what constitutes good or poor acoustics, what effects are desirable in an auditorium designed for speaking, and even more in one designed for music, is not a question in physics. The question is, however, of the utmost importance, for it is of little value to be able to calculate in advance of construction and express numerically the acoustical quality which any planned auditorium will have unless the quality which is desired is also similarly capable of numerical expression. On the other hand, if the owner and the architect can agree as to the desired result, and if this is within the limits of possibility considering all the demands on the auditorium of utility, architecture, and engineering, this result can be secured with certainty—or at least there need be no uncertainty as to whether it will or will not be attained in the completed building.

When a speaker delivers an address the sound proceeds from him in spherical waves to the boundaries of the room, unless it is absorbed on the way. At the walls it may be reflected or transmitted or absorbed. In general it will suffer all three kinds of treatment in relative proportions which depend on the character of the walls. Hard and smooth walls will reflect the major part of the sound, while porous and yielding walls will reflect very little. Eventually, after successive impact on different surfaces, the whole of the sound will be absorbed.

The effect of reflection is twofold. If the room is not too large the first effect will be to produce the same average loudness at different points of the room. In the case of a room 40 ft. square reflections will occur at least twenty-seven times a second.

On the other hand, if the walls are hard, little energy is absorbed at each impact and very many reflections will occur before the sound dies out. This produces slow decay or reverberation, which is the most common defect in audience halls.

The effect of reverberation on speech is readily understood. If the sound of one word is prolonged so as to blend with that of a subsequent one no word will be heard distinctly. In music reverberation produces an effect similar to that of the loud pedal in a piano. Some prolongation and blending of notes in music is desirable; but the mixing of words in speech is never an advantage. If a hall is to be used for both a middle course must be steered. The reverberation must be made somewhat too long for speech, somewhat too short for music, yet fairly satisfactory for both.

We have seen that a succession of reflections produces reverberation; in some circumstances a single reflection produces an echo, and echoes are the next most common defects in audience halls. The conditions necessary for the production of an echo are that the wall from which reflection takes place should be at such a distance from the hearer that the impressions formed by the direct and reflected sounds are quite distinct. The minimum interval that must elapse between the two effects for this to be the case is about $\frac{1}{15}$ of a second, though, of course, it varies for different observers. As the velocity of sound at 15° C. is 1,120 ft. per second this gives the minimum distance of the reflecting wall as $\frac{1120}{2 \times 15} = 37$ ft. The farther off the wall the more distinct is the echo.

A curved wall, as will be shown later, exercises a focussing action and produces regions of undue intensification and of comparative silence; it is almost inevitably a menace to good acoustics.

Besides these main defects it is also possible for the acoustics to be affected by resonance. Where a wall is elastic, but not too rigid, it may happen that the sound waves impinging on it have the natural period of the wall itself, in which case the wall will be set in considerable vibration, just as a heavy bell is set swinging by the small but suitably timed impulses of the ringer. Reinforcement will occur for sounds of this particular period, but not for others.

The effect on a band playing will be to accentuate some notes at the expense of others, and so to produce distortion. Similarly, it may happen that clear speaking is impossible for a voice of a certain modulation.

Resonance may occur not only by the vibrations of the walls, but also by the vibration of the column of air in the room as a whole. This is not as likely to occur in large as in small rooms—it is very marked in a small empty room such as a bathroom—but it does occur in buildings of a cruciform shape, as many churches are.

Sound waves are also subject to interference and to diffraction, and no treatment of the problem is satisfactory which ignores these. Interference occurs when the condensations of one set of waves fall on the rarefactions of a similar set and operates in the sense of producing a region or regions of silence, there being corresponding regions of intensification elsewhere. Diffraction consists in the bending of waves round obstacles and will generally assist in even distribution.

It is popularly supposed, and there are probably few ideas which are more prevalent and yet have so little foundation in experiment, that faulty acoustics may be cured by stretching wires across a room. How the idea arises it is difficult to imagine, for the small emission of sound by an isolated wire is an indication of its small capacity for absorption, and the effect on the sound in a room would be similar in degree to that of a fishing line on water waves. Indeed Sabine cites a case where the stretching of five miles of wire in a room made no perceptible difference to the reverberation.

A second idea is that sounding-boards, usually consisting of plane horizontal boards mounted above the speaker, have a beneficial effect. If they do so in certain cases it can only be regarded as fortuitous, for it is impossible to prescribe a general remedy for a defect due to so great a variety of conditions.

It has further been suggested that use might be made of the ventilating system to improve the acoustics of buildings. The idea has its origin in two observations, viz. that sound travels more readily with the wind than against it, and that in certain cases currents of hot air in the centre of a building have acted as a sound-screen, apparently carrying the sound away.

This matter has been investigated and discussed in detail by Sabine (2) and Watson (3), and their conclusion is that little if any improvement can be effected by a special system of ventilation. The case of the wind is not an analogous one, and in ordinary conditions of ventilation the difference of temperature between incoming and outgoing air is insufficient to permit the utilisation of reflection and refraction effects. Acoustic disturbances may, however, be caused by the presence of a hot stove in the centre of a hall, and the least injurious effect is probably produced by the commonest mode of ventilation in which the room as a whole acts as a kind of chimney.

It is assumed too that perfect acoustics are to be expected when a new auditorium is modelled on an old one whose acoustics are unobjectionable. This is apparently not borne out by experience, largely because the importance of detailed conformity to the model is not realised. As will be seen later, unless the new hall is constructed of similar materials and accurately to the same scale, its acoustics will not follow those of the model. And further, as will be shown, even though the proportions be the same, any great difference in size will alter the acoustics markedly in certain respects.

The general principle underlying the cure of reverberation is the introduction of material which will absorb the sound. The reverberation in an empty house is notorious, and the improvement effected by hanging heavy curtains is also a matter of common knowledge.

The reason is clear when one considers the nature of sound. Sound is a form of energy. It cannot be destroyed, it can only be converted into some other form. Some will escape through open windows, some will be used in imparting mechanical energy to the walls, some will pass directly by friction into heat. A hiss is very soon killed by air friction, and the frictional effects are increased by the presence of porous walls and hangings. It is only by true dissipative forces such as viscosity that sound can be so converted. No mere modifications by the introduction of irregularities are of any avail in this connection. The breaking up of smooth surfaces by relief work may eliminate echoes, but it does not cure reverberation unless the total absorbing surface is increased by the breaking up. The sound is still present and must be converted into energy of another form before it can cease to be heard.

The most important experimental work on reverberation was commenced by W. C. Sabine of Harvard in about 1896, and five years later a series of papers appeared embodying the results of these experiments (4).

The rate of decay of reverberation for a given sound was measured by measuring the duration of audibility of residual sound after the source had ceased. As the rate of disappearance of reverberation is proportional to the rate at which sound is absorbed, the experiments could be arranged to give information as to the relative absorbing powers of different substances. These experiments were carried out in the Fogg Art Museum in the University of Harvard. An organ-pipe C 512 was sounded by a constant pressure-blower and the time that elapsed after the wind was shut off before the sound became inaudible was measured by means of a chronograph. Preliminary experiments showed that the duration of audibility was almost independent of the positions of source and observer. The results of introducing cushions from the Sanders Lecture Theatre are given in the following table and curve (Fig. 1), the effectiveness of the cushions being practically identical wherever they were placed.[1]

| Cushions present (metres). | Time of Decay (secs.). |
|---|---|
| 0 | 5·61 |
| 8 | 5·33 |
| 17 | 4·49 |
| 63 | 3·94 |
| 128 | 3·00 |
| 162 | 2·64 |
| 213 | 2·33 |

The absorbing powers of various materials in terms of metres of these particular cushions were then determined for the same note, and yielded the following results :

| Square Metre of | Metres of Cushions. |
|---|---|
| Oil-paintings | ·28 |
| Carpet | ·20 |
| Oriental rugs | ·29 |
| Linoleum | ·12 |

The cushions of a particular lecture theatre are clearly not suitable units in which to express absorption coefficients, and Sabine next proceeded to determine absolute absorption coefficients, *i.e.* the ratio of the absorption of a given area of the surface considered to the same area of complete absorption. The nearest approach to complete absorption is the open window, and it was first shown that the absorbing power of a window was proportional to the area of the opening. The absorbing power of the cushions was then determined in terms of open window.

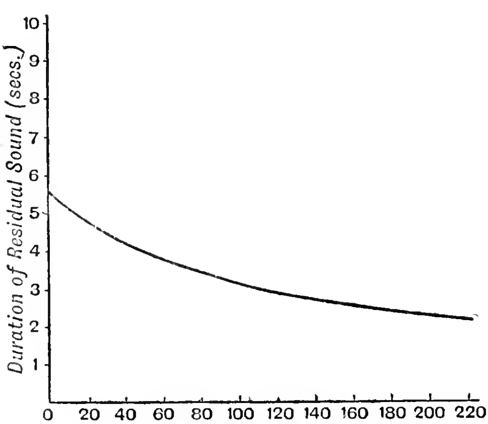



FIG. 1.

The curve in Fig. 1 is found to have the equation $(a + x)\ t = k$, *i.e.* it is a rectangular hyperbola with its origin displaced ; $a$ is clearly the absorbing power of the walls of the room in metres of cushions. In this case $a = 146$ and $k = 813$ and the calculated durations agree with those observed on the average within ·02 of a second.

[1] This is only true when the intensity in the room is uniform.

Similar experiments in different rooms varying in volume from 65 to 9,300 cubic metres gave a family of rectangular hyperbolæ as shown in Fig. 2, curves 1 to 7 being on one scale, 8 to 11 on a second, and 12 on a third. The parameters $k$ are found to be proportional to the volumes of the rooms, the mean value of $k/v$ being ·171.

The value of $k/v$ will depend on the intensity of the initial sound, and Sabine standardised his source as follows. Four organ-pipes similar to the source were placed in different parts of the room sufficiently far apart for it to be a justifiable assumption that when all were sounding together the intensity was four times that of the single pipe. Experiments were carried

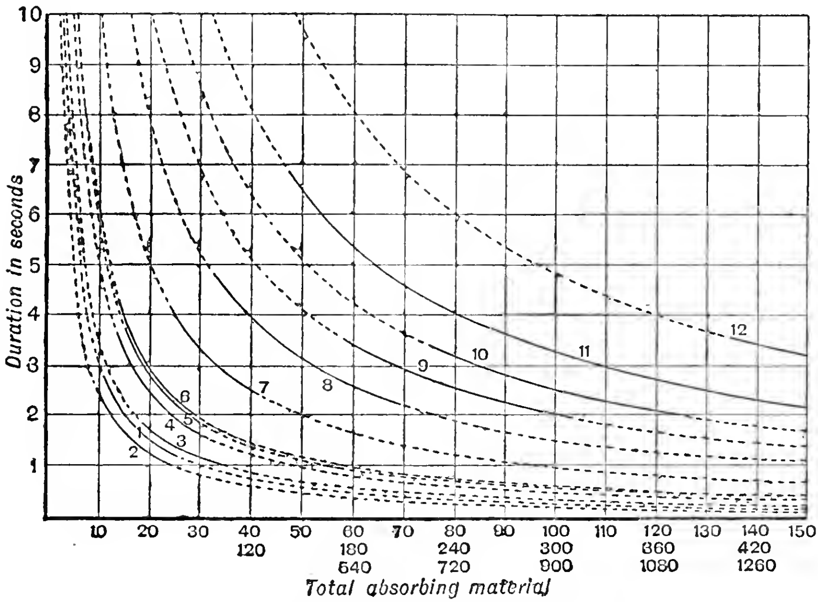



FIG. 2.—Three scales are employed for the volumes by groups 1–7, 8–11, and 12.

out to find the comparative duration of residual sound when 1, 2, 3 and 4 pipes were sounded. These yielded results which showed that the sound decayed logarithmically and hence the intensity I was found to be 10 million times the minimum intensity for audibility, $i_0$.

It is to be noted that the initial intensity of the sound in the room is slightly reduced by the introduction of the cushions, and when allowance is made for this the value of $k/v$ for $I = 10^6 i_0$ is ·164.

Thus Sabine's experiments give for the time of reverberation

$$t = \frac{\cdot 164 \, V}{a}$$

where $a$ is the total absorbing power of the room and contents. (If there are in the room surfaces $S_1$, $S_2$, $S_3$, etc., having respective absorption coefficients $a_1$, $a_2$, $a_3$, etc., then $a = a_1S_1 + a_2S_2 + a_3S_3 +$ etc.). This formula, together with the numerous values of absorption coefficients for various substances given in Sabine's tables (5) enables calculation to be made in advance of construction and was responsible for clearing up much of the fog that had surrounded the subject before the investigation.

SHORT TABLE OF ABSORPTION COEFFICIENTS

| | $a$ |
|---|---|
| 1 sq. metre of open window | 1·000 |
| glass, plaster, or brick | ·025 |
| heavy rugs | ·25 |
| hair felt | ·75 |
| audience | ·96 |

In the case of spacial units it is difficult to express the absorption as an absolute coefficient, and in the following table the absorption of each object is expressed in terms of a square metre of complete absorption.

| | |
|---|---|
| Audience per person | ·44 |
| Isolated woman | ·54 |
| Isolated man | ·48 |
| Ash settee | ·037 |
| Upholstered settee | 1·10 |
| Upholstered settee, per seat | ·28 |
| Upholstered chairs | ·30 |

The relatively high values for isolated units are due to the larger absorbing area presented when the objects are not in contact.

Other experimenters confirm the work of Sabine, and from theoretical considerations Franklin (6) deduced the formula, $t = \frac{\cdot 1625\ V}{a}$, which agrees with Sabine's experimental formula to 1 per cent. The theory has been extended by Jäger (7).

Jäger's theory applies to rooms whose dimensions are small compared with the velocity of sound, the length being not much greater than 20 metres, so that reverberation is sensibly uniform. The whole interior is supposed to be filled with sound-rays of equal intensity going in every direction, and equal volumes contain the same amount of sound energy. The energy density is taken as a measure of the prevailing intensity.

The absorbing power of a surface is defined as that fraction which, when multiplied by the energy of the sound, will give the average loss in energy suffered by a sound-ray in one reflection. Since for any ray all directions are equally probable, every ray will experience the same number of reflections per second, a number dependent on the size and the shape of the room. Applying statistical methods, Jäger shows that the maximum energy density, *i.e.* the maximum intensity attained, is given by :

$$E_0 = \frac{4A}{avS},$$

where $A$ = energy emitted per second.
$a$ = average absorbing power of the surfaces present.
$v$ = velocity of sound.
$S$ = total surface, including irregularities.

A being constant, $E_0$ is greater for small values of $a$ and S. Breaking up the walls by introducing irregularities tends to decrease the intensity attained. The removal or introduction of furnishings changes not only S, but also the average value of $a$. To find the effect on the intensity the change in $aS$ must be observed.

We have already seen that

$$aS = a_1 S_1 + a_2 S_2 + \ldots ,$$

hence it is clear that the maximum intensity attained is always weakened by introducing objects, including people.

When the sound has attained its maximum intensity $E_0$ its intensity E at a time $t$ afterwards is given by $E = E_0 e^{-\frac{avS}{4V}t}$, where $e$ is the exponential and V the volume of the room. This formula is the same in effect as Franklin's. The greater the absolute value of the exponent the quicker the decay. Since V cannot be altered without at the same time altering S, it is the ratio $\frac{S}{V}$ which is important in determining the reverberation. Hence the effect of extensive diversification of the walls is to reduce the time of reverberation. With increasing volume $\frac{S}{V}$ always decreases. Hence increasing volume has the effect of increasing the time of reverberation.

The dependence of reverberation on $\frac{S}{V}$ is an important point to note, for it shows that two auditoriums of exactly the same shape and constructed of similar materials do not have the same acoustical properties unless they are of the same size.

The formula

$$E = \frac{4A}{avS} e^{-\frac{avS}{4V}t},$$

shows that rooms acoustically good are restricted in dimensions. The desiderata are a fixed intensity of sound and a short period of reverberation.

The intensity is determined by the factor $\frac{4A}{avS}$. If with increasing volume and therefore increasing S the intensity is not to sink below a given value $a$ must be made small. In practice $a$ must be assumed greater than the lowest attainable value since larger rooms serve to accommodate larger audiences who raise the average value of $a$. Since then $a$ cannot be made arbitrarily small S should not exceed a certain value. So the improvement of acoustics by diversification of the surface has its limit. If carried too far the intensity of the sound will be influenced too much.

Since also a short period of reverberation is desirable, for speech about 1·5 seconds is most satisfactory, $\frac{avS}{4V}$ must be chosen correspondingly large. The considerations already put forward show that the numerator has an upper limit. Hence V is similarly limited in value. Further, if a room be too large it is intrinsically impossible to fashion it satisfactorily for sounds of limited strengths, *e.g.* chamber music. Hence an orchestra hall which is quite satisfactory for orchestral music where A is large may be quite unsuitable for chamber music. With rooms for speaking where the sounds are still more limited in strength and where shortness of reverberation is even more important, it is still more necessary that they be not too large, and Jäger considers that the poor acoustics of the Austrian Chamber of Deputies is predetermined in part by its large volume.

Jäger's theory also shows that the maximum intensity is not reached until a short time after the emission of the sound, a time which varies with the auditorium. The law of growth of intensity is found to be given by the equation

$$E = E_0\left(1 - e^{-\frac{a}{4V}t}\right).$$

Thus E attains the value $E_0$ when $e^{-\frac{avS}{4V}t}$ becomes negligible compared with 1. The attainment of the maximum must not take too long, hence $\frac{avS}{4V}$ must not sink below a certain value, the same condition as for short reverberation. In larger rooms a longer time will be taken to reach the final condition, and slow speaking will be advantageous. Similarly in large concert halls runs and trills should be taken more slowly than in small halls.

Jäger's work also indicated that in the case of a porous wall there would be more absorption for high than for low pitches, and Sabine extended his experiments to cover sounds varying in pitch from $C_1$ 64 to $C_1$ 4096 (8). As this extension was of importance chiefly in connection with music and as he had determined that his experiments should always be guided by practical considerations, he first conducted an investigation on the accuracy of musical taste.

At the recently built New England Conservatory of Music were a number of small rooms with plain wooden furniture which were to be used for practising. Under Sabine's direction a committee of musical experts listened to piano music in each of these rooms in turn and in each case cushions were introduced until the critics expressed themselves satisfied with the acoustics.

The times of reverberation were measured afterwards in the manner already described, and the results are set forth in the following table :

| Room Number. | Volume (cubic metres). | Absorbing Power of Room. | Persons Present. | Absorbing Power of Clothing. | Number of Metres of Cushions. | Absorbing Power of Cushions. | Total Absorbing Power. | Reverberation Period (seconds). | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 74 | 5·0 | 0 | 0 | 0 | 0 | 5·0 | 2·43 | Reverberation too great. |
| | | | 5 | 2·4 | 0 | 0 | 7·4 | 1·64 | Reverberation too great. |
| | | | | | 13 | 12·8 | 20·2 | ·60 | Reverberation too little. |
| | | | | | 11 | 10·1 | 17·5 | ·70 | Better. |
| | | | | | 8 | 7·3 | 14·7 | ·83 | Better. |
| | | | | | 6 | 5·5 | 12·9 | ·95 | Condition approved. |
| | | | | | 4 | 3·6 | 11·0 | 1·22 | Reverberation too great. |
| 2 | 91 | 6·3 | 0 | 0 | 0 | 0 | 6·3 | 2·39 | Reverberation too great. |
| | | | 6 | 2·9 | 0 | 0 | 9·2 | 1·95 | Reverberation too great. |
| | | | | | 7 | 6·4 | 15·6 | ·95 | Reverberation too little. |
| | | | | | 5 | 4·6 | 13·8 | 1·10 | Condition approved. |
| 3 | 210 | 14·0 | 0 | 0 | 0 | 0 | 14·0 | 2·46 | Reverberation too great. |
| | | | 7 | 3·4 | 0 | 0 | 17·4 | 2·00 | Reverberation too great. |
| | | | | | 12 | 11·0 | 28·4 | 1·21 | Better. |
| | | | | | 15 | 13·7 | 31·1 | 1·10 | Condition approved. |
| 4 | 133 | 8·3 | 0 | 0 | 0 | 0 | 8·3 | 2·65 | Reverberation too great. |
| | | | 7 | 3·4 | 0 | 0 | 11·7 | 1·87 | Reverberation too great. |
| | | | | | 6 | 5·5 | 17·2 | 1·26 | Better. |
| | | | | | 10 | 9·1 | 20·8 | 1·09 | Condition approved. |
| 5 | 96 | 7·0 | 0 | 0 | 0 | 0 | 7·0 | 2·24 | Reverberation too great. |
| | | | 4 | 1·9 | 0 | 0 | 8·9 | 1·76 | Reverberation too great. |
| | | | | | 10 | 9·1 | 18·0 | ·87 | Reverberation too little. |
| | | | | | 8 | 7·3 | 16·2 | ·98 | Better. |
| | | | | | 5 | 4·6 | 13·5 | 1·16 | Condition approved. |

Extracting from this table the times of reverberation when the acoustics were declared satisfactory, we have :

| Room. | Decay period (secs.) |
|---|---|
| 1 | ·95 |
| 2 | 1·10 |
| 3 | 1·10 |
| 4 | 1·09 |
| 5 | 1·16 |
| Mean | 1·08 |

This result is of considerable practical value, especially when one notes that the maximum departure from the mean is ·13 secs., and the average departure only ·05 secs.

Closer inspection of the large table reveals some interesting facts. The greatest deviation from the mean was in the case of room 1. In this room only it was suggested carrying the experiment further, viz. by removing two more cushions. The reverberation period was then 1·22 secs., and it was pronounced unsatisfactory; 1·22 is farther above the mean than ·95 is below, and if one more cushion had been removed instead of two the result might have been closer to the mean value. In every room the chosen condition came nearer the mean than any other condition tried.

As the rooms were of different sizes and the final numbers of cushions were 6, 5, 15, 10, 5, there could no question of prejudice. In three cases the final condition was reached from overloading, in two from underloading. Also before the experiments no explanations were given as to the method to be pursued.

This surprising accuracy of musical taste is probably the explanation of the rarity with which it is entirely satisfied, particularly when architectural designs are left to chance in this respect.

To explain the necessity of extending the reverberation investigation to different pitches Sabine cites the following example :

In an empty room with hard walls such as a church the reverberation for a violin (middle register) and a double bass-viol are about the same. The introduction of cushions diminishes the reverberation for both, but in different proportions, so that the reverberation for the double bass is now twice that for the violin. The presence of an audience increases the disproportion still further. Since a difference of 5 per cent. in reverberation is a matter for the approval or disapproval of musicians of critical taste the importance of considering these facts is obvious.

A further point of which account must be taken is the composite character of a musical tone. The quality of a tone depends on the relative intensities of the overtones, and it has been customary for physicists to regard these relative intensities as dependent simply on the source of sound. Primarily, of course, this is true. But while the source determines the relative intensities of the issuing sound, their intensities as heard depend not merely on that but also to a surprising degree on the room itself. Thus with an 8-foot organ-pipe for which the overtones were pronounced in an empty room the introduction of felt reduced the ratio of the 1st upper partial to the fundamental by 40 per cent., that of the 3rd upper partial by 50 per cent., and that of the 4th by 60 per cent.

With a 6-inch pipe, on the other hand, the effect was to accentuate the overtones, whereas all notes below the 6-inch fundamental were purified. The effect of an audience was still different, viz. to purify all notes up to $C_4$ 512, and to have very little effect on tones above this. For $C_1$ 64 the first overtone was decreased 65 per cent. relative to the fundamental and the second 75 per cent.

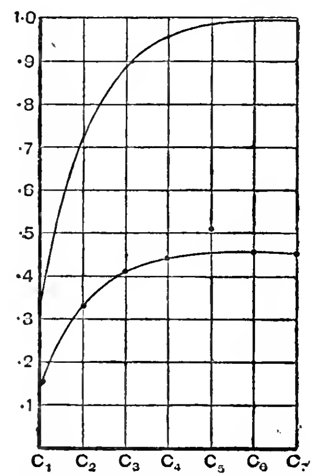



FIG. 3.—The absorbing power of an audience for different notes.

The musical effect will thus be injured or improved according to circumstances. The mixture stop in an organ is designed to be rich in overtones, the night-horn stop to be specially pure, and it may happen that the room in which they are sounded will completely alter the intended effects. To determine the balance must lie with musicians, and it is important that the judgment of musical authorities should be gathered in available form.

The necessity for extending the investigation to cover the whole musical scale has been demonstrated. Examples of the results obtained by Sabine are most conveniently given by the following curves :

Fig. 3 shows the absorbing power of an audience for different notes. The lower curve represents the absorbing power per person, the upper curve the absorbing power per square metre as ordinarily seated. The ordinates are fractions of one square metre of complete absorption. In the case of the upper curve the ordinates are thus ordinary coefficients of absorption. It will be noted that there is almost complete absorption for high notes.

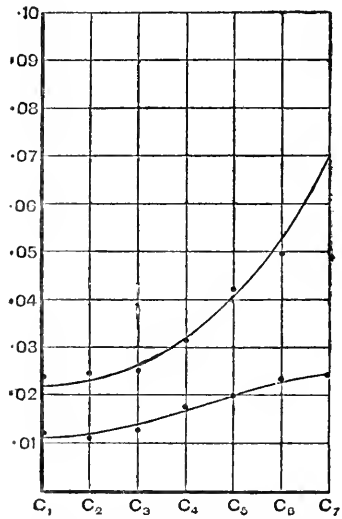



FIG. 4.—The absorbing power of 45-cm. thick brick wall.

The effect on absorption of painting a brick wall is shown by Fig. 4. Here the upper curve represents the absorbing power of the unpainted surface of hard but unglazed bricks set in cement. The lower curve gives the new absorbing power of the surface after the application of two coats of oil-paint. The difference represents the absorption due to the porosity of the bricks, and this is most marked, as would be expected, in the case of sounds of high pitch. The ordinates are absorption coefficients.

The absorbing power of cushions of different types is illustrated by Fig. 5. Curve 1 is for cushions of vegetable fibre, covered with canvas ticking and thin cloth. Curve 2 is for cushions of long hair covered with similar ticking and plush. The cushions of curve 3 are hair cushions covered with ticking and a thin leatherette, and those of curve 4 are of elastic cotton covered with ticking and short nap plush. All the curves show maxima due to resonance within an octave. In addition three of the curves have humps in a second octave. This may be due to secondary resonance.

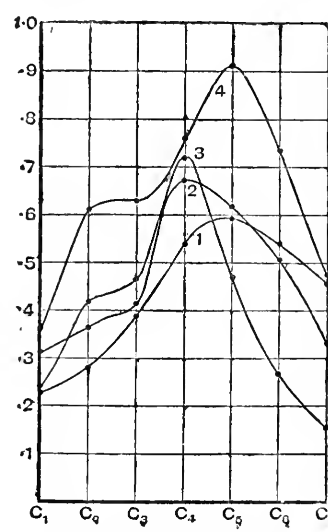



FIG. 5.—The absorbing power of cushions.

A special set of experiments was carried out to determine the nature of the absorption by felt of different thicknesses, and the results of these are given in Figs. 6 and 7.

In Fig. 6 the absorption coefficient is plotted against the pitch. The felt was 1·1 cm. thick, and curve 1 is for a single thickness, curve 2 for two thicknesses placed one on top of the other, and so on. It will be noted that the single thickness absorbs scarcely any sound for $C_1$, $C_2$, and $C_3$, that the absorption increases rapidly for $C_4$ and $C_5$, and is then practically constant. The absorption by greater thickness is greater in proportion for low notes than for high. All the curves show a maximum, each succeeding maximum corresponding to a slightly lower note. For six thicknesses the maximum is very near $C_4$.

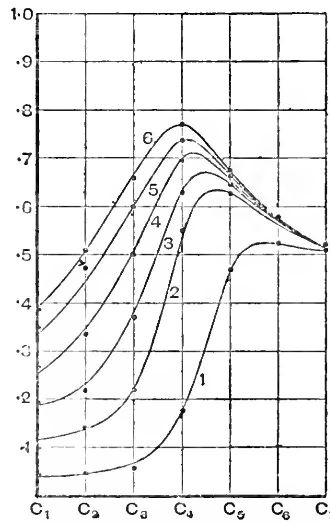


FIG. 6.—The absorbing power of felt of different thicknesses.

Absorption may be ascribed to three causes: Porosity, resonance (due to vibration), and surface friction. The maxima represent resonance.

Further information is afforded by Fig. 7, in which the same results are plotted in a different way. The ordinates are absorption coefficients and the abscissæ thicknesses of felt. There is one curve for each of the notes $C_1$, $C_2$, etc.

For $C_1$ the absorption is very nearly proportional to the thickness over the range tested. The curves for increasing pitch show increasing values for the coefficients of absorption. They all show that if the thickness of felt were sufficient a limit would be reached, which is, of course, obvious. For $C_5$, $C_6$, and $C_7$ this limit was reached.

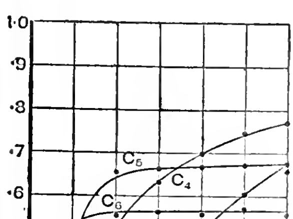


FIG. 7.—The absorbing power of felt of different thicknesses.

The curves of $C_1$, $C_2$, $C_3$, $C_4$, if produced, would pass through O. For these zero thickness would thus produce zero effect. Hence for these surface friction as an absorption agent is unimportant, so that roughening walls has little effect. The curves $C_5$, $C_6$, $C_7$ do not give evidence on this point.

Absolute absorption coefficients in Jäger's sense have also been determined for many substances by a special method by H. O. Taylor (9), and yield results which are in close agreement with those of Sabine. A new point which these experiments have brought out is the dependence of absorbing power on the distance of the absorbing material from the wall. This is natural, since the air near the wall is normally almost at rest and damping will therefore be less marked there than at some distance away. The following table for compressed cork illustrates this point:

| Distance from wall (mm.). | Absorption coefficient ($a$). |
|---|---|
| 2 | ·34 |
| 5 | ·38 |
| 10 | ·47 |
| 20 | ·61 |

Since reverberation varies for different parts of the musical scale, Taylor suggests that this result has a practical application in the case of an auditorium designed for music.

After reverberation the next most important defect in an auditorium is an echo. The echo may be got rid of in two ways. The form of the wall may be changed, and its surface broken up by relief work, or it may be made a perfect absorber. The first of these if carried out thoroughly enough to have any effect is almost certain to do violence to the architectural design. The second can only be accomplished by replacing the wall by open windows, an impossible change.

An important investigation on the elimination of echoes was carried out by F. R. Watson in an auditorium in the University of Illinois (10). The auditorium in question seemed destined to be an acoustic horror. The reverberation was first cured by Sabine's method, but echoes still made the hall acoustically bad. The echoes were detected most satisfactorily by means of an arc light at the focus of a parabolic reflector. The beam was directed to different wall surfaces in turn and the positions of the reflected beams noted. Owing to the curvature of many of the surfaces there were foci of sound as of light. The arc itself emitted a sound of high frequency which suffered little diffraction, and the path of reflected sound was traced out by the path of reflected light.

It is, however, to be noted that the path of the beam of light gives only partial information as to the path of sounds of ordinary wave length. These are much more susceptible to diffraction by obstacles, and have no such sharp outline as beams of light; also they require much larger surfaces for their reflection.

Watson's method of survey allowed a fairly complete diagnosis, and it was found that the echo defects were in the main due to the curved wall and ceiling surfaces.

An attempt was made to improve matters by the use of plane reflecting boards placed in different positions near the speaker, but these were of no avail. Considerable improvement was effected, however, by mounting a canvas reflector, whose surface was in the form of part of a paraboloid above and behind the speaker so that his head was near the focus. But such an arrangement was of no use when the origin of the sound was an orchestra, and it was finally abandoned. The effect of such a reflector has been discussed in detail by Tallant (11), and by him adopted as the most suitable shape for the rear wall of a large auditorium in the University of Michigan.

The offending surfaces in the Illinois auditorium were known from the diagnosis referred to, and very heavy materials were hung in such positions that they prevented reflection at these surfaces. In this way the hall was made suitable for speech, although at the sacrifice of features of the architectural design.

Another way in which diagnosis of the echo conditions of an auditorium can be effected in advance has been suggested and carried out by Sabine (12). A small model is made in accordance with the proposed plans, and actual sound waves inside the model are photographed. The form of the waves suggests necessary alterations in design, and this method has been used with success. This method has confirmed the view that a curved wall is almost always a menace to good acoustics.

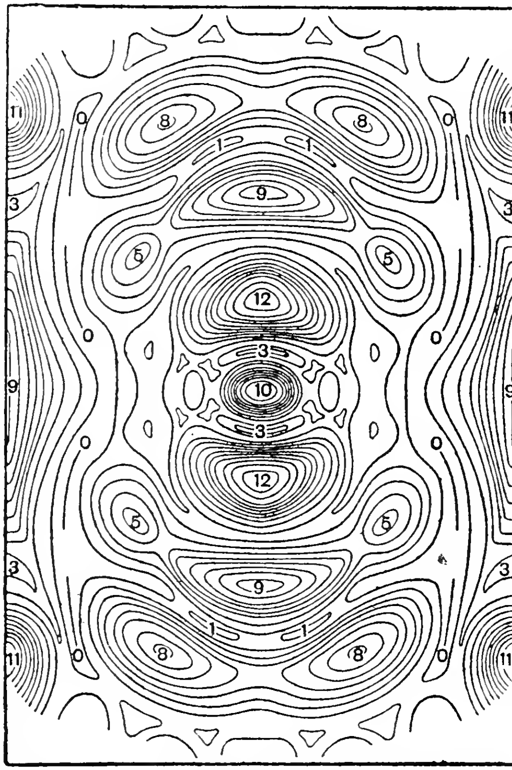


FIG. 8.—Distribution of intensity at the head level in a room with a barrel-shaped ceiling, with centre of curvature on the floor level.

The full nature of the effect of such a wall is best illustrated by Fig. 8, a diagram of Sabine's, showing the variation of intensity at head level in a room with a barrel-shaped ceiling, the radius of curvature of which was on the floor, the source of sound being in the middle of the room. Such an interference pattern, comprising regions of intensification and comparative silence, always occurs with a curved surface, a point verified by recent observations in St. Paul's Cathedral (13). A possible way of regarding these regions of intensification is as a series of main and subsidiary foci, the main foci being the points at which light would be concentrated by reflectors of the same shape. Watson's experience in the Illinois auditorium would seem to show that if sufficiently drastic measures are taken to destroy the main concentrations the subsidiary ones are eliminated also.

The effects of diffraction have been further considered by Tallant (14), who shows the importance of these in estimating the acoustics at points not far in front but at a considerable distance laterally from a speaker. His analysis confirms the view of Lord Rayleigh that a whisper is essentially a directed sound and shows that this applies, though in a less degree, to sounds of lower pitches. He concludes that the floor of an auditorium should be fan-shaped.

The question of acoustic isolation is a subject by itself, and it has received attention from W. C. Sabine (15), P. E. Sabine (16), F. R. Watson (17), and others. Lack of space precludes any account here of the experimental work done, but the conclusions reached are broadly these :

Sound-proof partitions should be as rigid and free from air-passages as possible. Any necessary openings for pipes, ventilators, doors and windows should be placed in outside or corridor walls where a leakage of sound will be less objectionable.

In the case of a sound generated in the building structure, *e.g.* by the vibration of machinery fastened to the floor, a break in the structure must be arranged so as to interpose a medium differing in elasticity and density. A layer of hair-felt or similar air-filled material might be placed between the base of the machine and the floor, but bolting through this material would almost destroy the insulation.

Special attention must be paid to the ventilation system ; without such attention it is a waste of effort to construct sound-proof walls, doors, etc. The system must either be omitted altogether or constructed in a special manner. Pipes small in diameter and extending without break from the air-supply chamber to the room have been successfully used.

The conclusions of this review of existing data may be summarised thus :

Sufficient information is available to enable satisfactory acoustics to be ensured in advance of construction, the general principles to be followed being :

(1) The size of the room must not exceed certain limits.

(2) Curved walls are almost always bad, a partial exception being the case of a paraboloidal wall behind the speaker. If there is doubt in any particular case the matter can be settled by constructing a small model of the room and photographing sound waves in it.

(3) When the size and shape have been fixed the materials

of construction must be chosen so that the time of reverberation calculated by Sabine's formula will be within the limits regarded as satisfactory under the conditions which will ordinarily prevail in the auditorium.

In the case of buildings already constructed excessive reverberation can be reduced by the introduction of suitable absorbent material. Echoes, including sound foci, can be eliminated by determining the surfaces responsible for their production and altering these or preventing the sound by suitable absorbent sheets from striking them.

The problem of acoustic isolation has also been scientifically investigated, but here the information is less complete than for the satisfactory design of auditoriums.

1. Roger-Smith, T., *Acoustics in Relation to Architecture and Building.*
2. Sabine, W. C., *Engineering Record,* lxi, pp. 779–81, 1910.
3. Watson, F. R., *Engineering Record,* lxvii, p. 265, 1913.
4. Sabine, W. C., *Engineering Record,* i, 1900 ; also in *American Architect,* lxviii, 1900.
5. Sabine, W. C., *The Brickbuilder,* xxiii, pp. 1–6, 1914.
6. Franklin, W. S., *Physical Review,* xvi, pp. 372–4, 1903.
7. Jäger, S., *Sitzungsberichten der Kaiserl. Akad. der Wissenschaften in Wien Matem.-naturw. Klasse,* bd. cxx, abt. iia, Mai 1911.
8. Sabine, W. C., *Proc. Amer. Acad. of Arts and Sciences,* xlii, 2 June 1906.
9. Taylor, H. O., *Physical Review,* ii (2), p. 270, 1913.
10. Watson, F. R., *Bulletin* 87 *of the University of Illinois Engineering Experimental Station,* 1916.
11. Tallant, Hugh, *The Brickbuilder,* xxii, p. 169, 1913.
12. Sabine, W. C., *American Architect,* civ, pp. 257, 279, 1913.
13. Raman, C. V., and Sutherland, G. A., *Proc. Roy. Soc.,* A., vol. C., 1922.
14. Tallant, Hugh, *The Brickbuilder,* xxii, p. 225, 1913.
15. Sabine, W. C., *The Brickbuilder,* xxiv, pp. 31–6, 1915.
16. Sabine, P. E., *American Architect,* cxviii, pp. 102–8, 1920 ; cxx, pp. 215, 266, 1921.
17. Watson, F. R., *Bulletin* 127 *of the University of Illinois Engineering Experimental Station.*
18. Michel Eugen, *Hörsamkeit Grosser Räume,* F. Vieweg & Söhn, Braunschweig, 1921 : a résumé of the subject which the writer has not yet had the opportunity of consulting.

# POPULAR SCIENCE

## COLLOIDS, OR THE MATERIAL OF LIFE

By S. C. BRADFORD, D.Sc.

*(The Science Museum, London)*

The study of crystals may be said to be as old as chemistry. In the Latin writings that purport to be the translations of those of the Arabian alchemist Geber, the process of crystallisation is described, together with the principal chemical operations such as distillation, filtration, and sublimation. In fact the development of chemical science has depended, in no small degree, on the possibility of this method of separating substances in the pure state. Doubtless the importance of the crystal has contributed to the neglect, by chemists, of the tarry and resinous materials that form a considerable part of the yield of many of their processes. Except, however, for the products of the laboratory, crystalline substances are rare. Few of the objects seen around, whether natural or artificial, are definitely crystalline. Their composition is amorphous or colloidal. Crystals are found in mineral deposits and the primitive rocks of the earth's crust ; a number are valued as gems. But the materials of the surface, such as clay, flint, and chalk, are mainly colloid. Except for sugar, our food is colloid. Some items, such as jelly, starch, and milk, are typical of this state. Indeed, the name " colloid " is derived from *colla*, the Latin for glue or crude gelatin.

The practical applications of colloid materials are so widespread that volumes might be devoted to their description. Processes essentially colloid in their nature have been employed from early times. Instances may be found in brick-making, tanning and dyeing, the manufacture of paper and soap, and the extraction of sugar. Among the colloid articles of everyday use may be mentioned, soils, slates, concrete, pottery, glass, textiles, wood, rubber, pitch, resins, varnishes, paints, adhesives, and photographic plates. Merely to enumerate them all would be tedious. Evidently the science of colloids is of very wide applicability. But, perhaps, it is in the biological field that the subject is finding the most interesting of its applications. The properties of living things are intimately connected with their colloid condition, and colloid chemistry has already gone a long way towards the explanation of the fundamental processes which take place in the organism.

Although its foundations were laid by Graham some sixty years ago, most of our knowledge of colloids has been acquired during the last two or three decades. The rapid progress of the science, together with the far-reaching importance of its applications, make it peculiarly fascinating for study. What, then, is the fundamental distinction between "crystalloid" and "colloid," to which the striking properties of the latter condition are due? How does the state of a lump of washing-soda or sugar differ from that of a piece of jelly? Merely in the size of their ultimate particles. A crystal of soda is built up of an ordered arrangement of the molecules of that substance alone. Excepting those in the surface layers of the crystal, each molecule of soda is surrounded by others of like kind. The substance is the same throughout. On the other hand, a piece of jelly or charcoal is composed of an enormous number of extremely tiny particles of gelatin or carbon, too small to be seen with the most powerful microscope, but which are yet larger than single molecules, and the spaces between the particles are filled with liquid, or air, as the case may be. Ultimately the substance is granular. It is to this extremely fine subdivision that the properties of colloids are due. In this condition the surface area of the particles has been developed enormously in comparison with their bulk. Now molecules in the surface layers of a particle are in a condition very different from that of those in the interior. The latter are subject to molecular attraction in every direction, so that the bulk of a substance is under an enormous pressure, to which its cohesion is due. In the case of a liquid like water the internal pressure amounts to over 10,000 atmospheres. In many solids it must be very much greater. Since molecules in the surface skin are not attracted by similar particles on the outside, the internal pressure falls off, through this layer, to that of the air or medium with which the body is in contact, and there is a free external force of attraction, emanating from the molecules in the surface, which is exerted upon anything coming within the small radius through which these universal molecular forces are appreciable. Such unbalanced forces are experienced at the surfaces of all bodies. With liquids they give rise to the effects of surface tension, as when a small quantity of water collects into a drop. Probably they are greater in solids, though less easy to observe. But, although of much interest, surface phenomena are not strikingly noticeable, except in the case of colloids. Here the specific surface is so enormous that surface effects transcend in importance the intrinsic properties of the substances concerned. Thus in the study of colloids we come into contact with the tremendous forces experienced by the molecules of matter. Indeed it may be said that colloids are matter in the nascent state. No wonder, therefore, that their properties should be astonishing.

So far, two types of colloid condition have been studied in detail: sols, or colloid solutions, and gels, or jellies. Other types, as glasses and resins, appear to resemble gels, but differ in being formed from a cooling melt and having no liquid phase. Others, again, as starch, charcoal, and cellulose, have their interstices filled with air instead of liquid.

Colloid solutions, or sols, are distinguished by the presence of particles of a size intermediate between those of ordinary solutions and those of suspensions of solid matter in liquids. In so-called true solutions the particles of dissolved substance are comparable in magnitude with those of the solvent. Doubtless there is a field of force surrounding each dissolved particle, but these are so small that it seems impossible to detect their individual existence, and the solution appears to be practically homogeneous. On the other hand, although the dispersed particles in sols are still too small to be seen directly with the most powerful microscope, yet their size is sufficient to bring them within the range of the more delicate apparatus of modern research.

When an extremely powerful beam of light is transmitted through a colloid solution at right angles to the axis of the microscope, the light is scattered by the dispersed particles, some of it enters the microscope tube, and the particles are seen as points of light against a dark background. Such an arrangement is called an ultramicroscope. The appearance presented is indeed amazing. Thousands of tiny particles, bright as sparks of emerald or ruby, or shining like gold, are seen to be dancing like gnats in a sunbeam. They hop, jump, dash together and fly away again, and the motion continues for ever. It has been demonstrated that the effect is not due to vibration or to any external cause. Here for the first time we have visible evidence of the endless dance of the atoms that will cease only when the heat energy of the universe is completely dissipated and all matter is cooled to the absolute zero of temperature. The colloidal particles are small enough to exhibit, in less degree, the attributes of molecules themselves. And this is the great fascination of colloid chemistry, that in the conduct of colloid particles we can trace the behaviour of the invisible molecules. Thus, the energy of motion of the particles has been measured, and found to be exactly that which would be possessed by molecules of similar mass, or produced by collision with the invisible molecules of the liquid. It is one of the triumphs of colloid chemistry that, in this way, it has been successful in demonstrating what, hitherto, even chemists have sometimes doubted, the real existence of molecules.

One of the most important properties of colloid particles is the low rate of diffusion that results from their larger size. For this reason such particles are retained by colloidal membranes, like parchment and gold-beaters' skin, while crystalloids can pass through into the water in which the membrane is immersed. Graham utilised this property for the separation of colloids and crystalloids, and his method of "dialysis" is still one of the fundamental operations of colloid chemistry. This slowness of diffusion is responsible, also, for the curious hysteresis of colloid phenomena that is so suggestive of an analogy with vital processes. Indeed, a slow rate of diffusion appears to be essential for the existence of living matter. The cells of organisms are surrounded by precipitation membranes, through which the colloid contents of the cell are unable to pass. The substances which can permeate the cell walls, and cause physical or chemical changes in the material within, vary according to the nature of the membrane. Thus the properties of cells are differentiable and each cell becomes a diminutive chemical factory.

The cell walls are formed by a process, also characteristic of colloid solutions, i.e. the tendency to form skins on the surface. Such membranes may be produced by contact with a precipitating reagent, or may be evolved spontaneously. The latter case is particularly interesting as resulting from the diminished internal pressure in the surface layer of a liquid. Water molecules appear to attract one another more than the colloid particles, so that the latter tend to be squeezed out into the external layer in spite of their kinetic energy that continually returns many of them to the bulk of the liquid. This collection of solid in liquid, or solid, surface layers is called "adsorption." If sufficient colloid collects at the surface it may be thrown out of solution and form a solid skin. The effect is familiar in the case of hot milk. Such precipitation membranes have remarkable properties. When produced around a crystal suspended in a solution with which, when dissolved, it forms a colloidal precipitate, the membrane grows like a plant, sending down roots into the liquid, and stems and branches which sometimes grow out of the solution into the air. Moreover, such plant-like forms exhibit the properties of youth, maturity, age, and decay, just like living organisms. By merely dropping gelatin solution into a solution producing quick coagulation, Hatschek has produced forms closely resembling those of medusæ and other aquatic beings.

Another suggestive property of colloids is their power of greatly accelerating chemical changes that, otherwise, would occur to an inappreciable extent. The " catalytic " power of finely divided platinum is utilised in a popular type of gas lighter. When brought within the stream of gas, energetic combination with the oxygen of the air is induced, and the heat evolved is sufficient to kindle the gas. A sheet of the metal is able to bring about the gradual combination of oxygen and hydrogen. The more intense effect of the " platinum black " is due to the increased surface. The actual part played by the platinum in such reactions has been much discussed. It has been suggested that a hydride of platinum is formed, that the gases are dissolved in the metal, or that they are adsorbed at the surface. It is becoming increasingly evident, however, from consideration of the electrical structure of matter, that the attractive forces exerted by molecules are the same as those causing chemical combination. Whether the phenomenon be regarded as physical or chemical, it is probable, therefore, that the unlike gaseous atoms are brought so close together under great pressure, by the forces exerted at the metallic surface, that the comparatively weak fields of force between the like atoms composing the gaseous molecules are disturbed, the greater attraction between the unlike atoms comes into play, and a compound of oxygen and hydrogen is formed.

In such a chemical change as we have described the " catalyst " is recovered intact after the action, and a very small amount of catalyst is able to transform a large amount of material. Catalytic reactions are of great and increasing importance in chemical technology. Spongy platinum is used to determine the combination of sulphur dioxide with oxygen in the " Contact " process of sulphuric acid manufacture. Finely divided nickel may occasion the change of acetylene into various kinds of petroleum according to the temperature. The same metal, and others, are used in a process, known as the hydrogenation of oils, whereby liquid unsaturated hydrocarbons are converted into solid edible fats for making margarine. The bulk of the world's production of formalin is made from wood-spirit and air through the agency of a metal catalyst. The catalytic synthesis of ammonia, from the nitrogen of the air and hydrogen, made it possible for Germany to continue the war when foreign sources of combined nitrogen had been cut off.

Apart from their commercial importance, however, catalytic changes are of the greatest interest in consequence of their occurrence in the living organism. The cellular reactions are regulated by the presence of specific bodies known as enzymes. These are organic bodies in the colloid state, whose chemical structure is as yet unknown. Their general characteristics and individual properties are, however, sufficiently established to leave no doubt of their existence. Their general properties are exactly similar to the known catalysts. For instance, a colloidal solution of platinum may be prepared by passing an electric spark through water between two threads of the metal. The platinum gradually disintegrates, the liquid turns yellow and finally brown. Three hundred litres of this solution contain about one gram of platinum in an extreme state of subdivision, the particles having a size of only some hundred thousandths of a millimetre. By this and other methods, sols of gold, silver, cadmium, iridium, and numerous other substances have been prepared. Examples are shown in the Science Museum, South Kensington. Some of them are beautifully coloured, or exhibit a characteristic opalescence. Such a platinum sol decomposes hydrogen peroxide, reddens aloin, turns guiac blue, and is characterised by an optimum temperature. It is first activated, then inhibited, by a trace of alkali, and its action is destroyed by poisons such as prussic acid, sulphuretted hydrogen, and mercuric chloride. It has, in fact, quantitatively, the properties of an oxidase, a definite class of enzyme. The study of biochemical catalysts has already gone a long way to explain the assimilation by plants of carbon, hydrogen, and oxygen, their condensation into carbohydrates, the origin of fats, the decomposition of these substances in the organism, the functions of nutrition and respiration, and divers other phenomena of life.

Of many other characteristic properties of colloidal solutions, their electric charge, their precipitation by salts, its analogy with the coagulation of the blood and the agglutination of bacteria, and the utilisation of the opposite effect in the transfusion of blood, which saved so many valuable lives during the war, space forbids us to speak. We pass to the consideration of the second type of colloid condition—the gel state.

The coagulation of a sol results, as a rule, in the formation of either a gelatinous precipitate or a jelly occupying the whole volume of the liquid. The transformation may be permanent or reversible. The coagulation of egg white by heat is an example of the former change, the setting of a hot gelatin solution illustrates the latter. The structure of gels has been a matter of controversy until the present time. Consideration of the causes of " gelation " has indicated the general solution of the problem. We have to inquire why a hot concentrated solution of soda should deposit crystals on cooling and a gelatin sol set to a jelly. Only little by little has the necessary evidence been collected. Graham thought that the colloid or crystalloid condition was characteristic of a given substance, that colloids and crystalloids were two separate classes of natural substances. Soda was essentially a crystalloid, gelatin a colloid. This view has changed slowly. It was gradually realised that bodies might occur in either state, and eventually, in 1914, von Weimarn showed, from experiments with a variety of materials, that, by the suitable choice of conditions, a given substance could be obtained in either state desired.

The condition in which a body will be formed depends upon its solubility, the excess concentration of substance that will be thrown out of solution, the size of the particles in solution, and the viscosity of the solution or rate of diffusion of the particles. A large solubility and small excess concentration cause large crystals. When the particles in solution are not aggregated, their constitution is simple and they are able to diffuse freely; again, large crystals tend to be formed. All these conditions are fulfilled in the case of soda. On the other hand, a substance with a very small solubility, like barium sulphate, occurs in the form of very small crystals. By simply increasing the supersaturation as much as possible, the crystals of barium sulphate become so small as to be beyond the range of the microscope and a translucent jelly is obtained. These principles have been embodied by von Weimarn in a simple formula, which, although not quite exact, proves most useful as a working rule. Should a varnish prove permeable to moisture, von Weimarn's formula indicates the remedy. If the products of a manufacturing process are difficult to deal with, the same expression shows how to modify them.

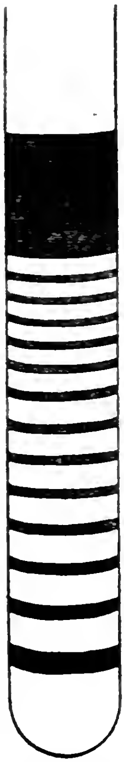
It has now been demonstrated that gelatin and other substances that occur naturally as colloids obey von Weimarn's law. Gelatin has a small definite solubility which increases rapidly with rising temperature. Its particles in solution are very complex and diffuse very slowly. A hot solution contains very much more gelatin than it can retain in the cold. All the conditions, therefore, contribute to the formation of particles below microscopic size.

Gelatin has rarely been prepared in another state. But, if no more is dissolved than corresponds to its true solubility in water, gelatin forms a clear solution. With gradually increasing concentration the solution first becomes supersaturated and then deposits a precipitate, of which the particles decrease in size and increase in bulk until, when sufficient gelatin is present, the precipitate fills the solution and forms the ordinary well-known jelly. In this state, the mother liquor, from which the gelatin has been deposited, is held by capillary attraction and by the molecular forces exerted at the surfaces of the enormous numbers of invisible particles.

A gel, then, is merely a mass of crystals of below microscopic size, in which the mother liquor is retained. Here, again, the enormous specific surface confers upon the condition peculiar properties. The most noticeable of these is a remarkable attraction for water and other substances. Ordinary air-dry gelatin still contains about 15 per cent. of water. And this can be driven off only by heating for hours. In fact this water is held as firmly as the water of crystallisation in many salts. When the dried gelatin is exposed to the air, the moisture is absorbed so vigorously that the gelatin rapidly increases in weight. A piece of ordinary gelatin placed in water gradually drinks it up and swells until it has absorbed as much as ten times its weight. The energy of combination with the water is shown by the considerable heat evolved and by the fact that the swollen gelatin occupies less volume than the total volume of the gelatin and water before swelling. The tremendous pressures developed during this contraction are demonstrated by the force needed to squeeze out the water. Forty atmospheres pressure reduce the water content only to about 30 per cent. It can be calculated that tens of thousands of atmospheres would be necessary to force out all the water. This swelling process is the mechanism by which the growing plant cells are able to take up the moisture they need from the ground.

Suppose, however, a gelatin jelly is immersed in water which has been coloured with a suitable dyestuff. Then the colouring matter is extracted from the solution until it is nearly colourless. The same thing occurs with charcoal, silicic acid gel, and kaolin. It appears to be characteristic of colloid bodies. With textile fibres it becomes the process of dyeing. Here again the mechanism of the action has been the subject of endless discussion. As in the case of catalysis, we are concerned with the molecular forces operating at the colloid surface. There are separate schools which favour dissolution of the dyestuff in the fibre, chemical combination, electrical attraction, and adsorption. Since the forces involved are probably the same in each case, there is much to be said for each of the different theories.

One striking property of gels must be referred to in conclusion. In many cases, when a reagent is allowed to diffuse into a gel containing a substance with which a precipitate can be formed, the precipitation does not take place continuously as would be expected, but the precipitate is deposited in bands separated by more or less clear spaces. This curious phenomenon, first observed by Lupton, was rediscovered and investigated by Liesegang, and is frequently known as Leisegang's rings. Leisegang placed a drop of strong silver nitrate solution on a glass plate coated with gelatin containing a trace of potassium dichromate. As the silver salt diffused into the gelatin the insoluble silver dichromate was precipitated in rings surrounding the drop. The same thing happens when the reagent is poured on top of the gel contained in a test-tube as shown in the figure. Bands are produced with many pairs of reagents, in some cases with very beautiful results. The distance apart of the rings or strata varies in different cases from a fraction of a millimetre to a centimetre or more. A good deal of attention has been given to the subject, from which it appears that the effect is due, in the main, to exhaustion of the soluble reaction component from the layer of gel adjacent to each band. The banding occurs only when the precipitate has large specific surface. The reagent is adsorbed from the gel by the molecular forces residing in the surface of the precipitate. When all the reagent has been extracted from the region of gel next to the precipitate, no more of the latter can be formed, and the precipitating reagent, diffusing into the gel, passes through the exhausted zone to a region where more of the dissolved salt is available for the formation of a fresh band. This banded structure is found in a great many different varieties of minerals. Liesegang showed that the rings of agates are formed in this way. Recently it has been suggested that the bands of flint in chalk are another case. Probably many points, hitherto obscure, in connection with the origin of mineral deposits are capable of similar explanation. In biology the phenomenon may prove to be of much importance. Various tissues have this lined aspect. This is the structure of muscle. In many cases the wings of insects and the plumage of birds show the same banded appearance. To their striated surface must be ascribed some of the most beautiful colours of nature: the fire of the scarab beetle, the colours of the peacock, and the iridescence of the pearl.



Silver chromate bands in agar jelly.

Of the two problems of transformation of supreme consequence to biologists, the artificial metamorphosis of one species of animals or plants into another may be said to have been solved, as is evinced by the continual introduction of improved varieties of flowers and vegetables. The other problem, the artificial transmutation of dead into living matter, remains unsolved. Yet every day we see the change brought about by the agency of plants and animals. We know that the chemical reactions which take place in living matter do not differ in principle from those in dead matter. It cannot reasonably be predicted, therefore, that the synthesis of living organisms is impossible. The study of colloids encourages the hope that eventually the mystery of life may be solved.

# NOTES

**Scientific Politics.—III. "The Will of the People."**

The essential theory of parliamentary government is that a parliament is elected by the common will for the common good; but it is clear that the definition implies a great deal more than appears in its actual words. It is in fact a tacit expression of faith; it assumes prior assent to a creed which demands belief in a political trinity—the existence of a common will, the competence of that will to judge of individual character, and the assurance that those who are selected by the common will are both capable of fulfilling and in fact ready to fulfil their trust.

Every clause of this unwritten creed which lies at the base of popular government has been challenged. It has been pointed out that individual members and even whole parliaments have acted selfishly, foolishly, or corruptly; how then can they be said to fulfil their trust? The competence of the people to choose their rulers has been denied: "The best part of a community is always the least, and of that least part the wiser are still less," said Winthrop, first Governor of Massachusetts three centuries ago, in words that have not yet lost their sting. And acute observers have doubted the very existence of a common will. It is true that T. H. Green and Bosanquet, with some reservations, admit its reality; but Laski, in the recently published *Foundations of Sovereignty*, disputes their conclusions. He holds that there is no general will, but only one which, when it prevails, may be the will of an energetic minority which has captured power.

It is with the last of these assumptions that we are here concerned. What light does political history throw upon the problem of the communal will?

The first paradox that we encounter is so familiar that it seems more like a truism than a paradox. The State is a political unit, and therefore the political will of the people should also be a unit. Yet the will of the people in parliamentary affairs appears automatically to divide into two—a majority (which forms the Government) and a minority (which forms the Opposition). And this at once distinguishes responsible parliamentary government from all other forms of government;

for under any other form of rule a minority always rules the majority.

The will of the people is therefore divided into a greater and a less—which seems at first sight destructive of the theory of a common will. But the fact that a Coalition Government was formed in time of war, and that party distinctions were then submerged, indicates that the common will may always have a real existence, but that it only functions occasionally. It becomes active when the State is directly threatened ; when it is not so threatened, it lapses. The truth of this is obscured for us because the security of the State is not often directly threatened ; in other words, peace is normal, war is abnormal. If the position were reversed—as it sometimes was in earlier conditions of society—the common will would be more continuously operative. And this seems to be true of every form of State. The will of the people is united for defence or aggression ; it is divided on questions of internal organisation or development.

It follows necessarily that political parties are agreed on fundamentals and divided on secondary issues. The truth of this is again obscured by the smoke and thunder of party strife, the exaggeration of party oratory, and the sheer love of a fight ; but as a general proposition it is not in doubt. For if parties are divided on fundamentals, civil war ensues and parliamentary government is destroyed. The last division on fundamental issues in English history was in the contest between Royalist and Roundhead, which led to the execution of the King, the temporary abolition of the House of Lords, and the purge of the House of Commons.

Our present parties derive their origin from that conflict ; Conservative and Radical are the pale shadow of Royalist and Roundhead. But it was not until sixty years after the Commonwealth that the two-party system divided the control of the State, and even then there was no such thing as " the swing of the pendulum." From 1714 to 1770 the Whigs held office without a break ; from 1770 to 1830—with the exception of a few months' Coalition in the disastrous year 1782, and a short-lived Whig Ministry in 1806—the Tories ruled the State. No serious student of the times will suggest that the " will of the people " had much to do with these alternations of power. The fact that the first two Georges were more Hanoverian than English favoured the long Whig domination ; the character of George III and the circumstances of the times established their Tory successors.

In 1832 the electorate was enlarged by the Reform Bill, and from that time the alternation of Conservative and Liberal is steady and regular—so regular, indeed, is the change that at first sight it seems to support the idea that the popular will is as vacillating and unstable as the strongest critics of democracy have maintained. But the very regularity of these periods suggests that something more is at work than the arbitrary whims of a mere inconstant mob; we seem to be in presence of a periodic force whose working, although concealed, is continuous and recurrent, and which should therefore be sufficiently rational to yield its underlying law to analysis.

A close examination of consecutive election figures soon furnishes a working hypothesis. In 1885 and 1892 the Liberals had a majority; in 1895 and 1900 the Conservatives; in 1906 the Liberals again secured a majority.

| | | | |
|---|---|---|---|
| The actual Conservative vote in | 1885 | was | 1,935,216 |
| ,, ,, ,, ,, | 1895 | ,, | 1,780,753 |
| ,, ,, ,, ,, | 1900 | ,, | 1,676,020 |
| ,, ,, ,, ,, | 1906 | ,, | 2,463,608 |

We have therefore the apparent anomaly that the Conservatives polled more votes in 1885, when they lost the election, than in 1895 or 1900, both of which elections they won; while their largest poll was in 1906, when they lost by a very large majority.

The Liberal figures explain this anomaly.

| | | | |
|---|---|---|---|
| The actual Liberal vote in | 1885 | was | 2,156,952 |
| ,, ,, ,, ,, | 1895 | ,, | 1,657,856 |
| ,, ,, ,, ,, | 1900 | ,, | 1,520,285 |
| ,, ,, Liberal-Labour vote in | 1906 | was | 3,111,929 |

The total electorate in 1885 was 5,707,531; of whom 4,092,168 voted. At the two following elections the natural increase of population involved a small increase in the number of possible voters—there was no change in the franchise—but the total number of votes cast was smaller in 1895 than in 1885, and smaller in 1900 than in 1895. In 1906 the number of possible voters had again increased, but this time there was a very large increase in the actual number of votes polled; with the curious result that the Conservatives suffered their greatest defeat at the election at which they polled more votes than they had ever done before.[1]

[1] Consideration of the 1918 election is omitted, as the conditions were abnormal. The electorate was largely increased, the number of potential voters being 21,392,322; but 106 constituencies were uncontested, which deprived nearly 7,000,000 persons of a vote, on the average calculation that one member represents 65,000 persons. Many voters were away at the war, many more were far from their homes; thousands who were on the register were already dead, the election having followed immediately the outbreak of influenza. In these circumstances, the fact that 10,781,025 electors voted must be considered extremely high.

The figures, or at least their results, seem therefore to contain an irrational element. But the explanation is rational enough, and on the whole it supports those who believe that "the will of the people" exists and that it is neither capricious nor vacillating.

(i) The very large discrepancy between the number of votes pollable and polled is partly explained by the fact that in some constituencies there was no contest, and therefore no votes were cast on either side. But where a party or a candidate does not think it worth while to contest a seat, the presumptive evidence is strong that the other party is in a very large majority. The will of the people is so strong that there is no object in challenging it.

(ii) But uncontested seats do not account for anything like the whole discrepancy between votes pollable and polled. Many voters abstain, either through indifference or because they object to a particular candidate or are out of sympathy with their party at the moment; they will not vote against their party, but they will not vote for it. This was notoriously the case with many Liberals in 1895 and 1900, and with many Conservatives in 1906.

Those who refuse to contribute to the expression of the general will from pique or laziness or resentment may easily lose an election for their party, and they are thus a negative factor of great and sometimes decisive importance to the candidate and his organisation. It is the existence of this lukewarm element which inspires the elaborate propaganda and canvassing, and all those attempts to raise the enthusiasm of the crowd which are of profound interest to the psychologist as well as to the politician.

The figures show clearly enough that this type of occasional voter is more numerous on the Liberal than the Conservative side of politics. If the Liberals had polled as many votes in 1895 and 1900 as in 1885 they would have won those elections, since the Conservatives registered fewer votes in 1895 and 1900 (when they won) than in 1885 (when they lost). It was only because the Liberals were able to bring practically every man to the poll in 1906 that they beat the record Conservative vote of that year.

The explanation of this apparently curious discrepancy between the dispositions of parties is probably that the Liberal looks on his politics as a crusade, and is therefore more likely to vote to the last man when he is enthusiastic, and to sulk in his tent when he is not particularly stirred. The Conservative from his very nature takes the middle course: he is never so enthusiastic, and never so utterly discouraged, with the result that he is a more dependable voter, both in good times and bad.

(iii) The figures in detail, when examined constituency by constituency in a series of several elections, give very little support to the prevalent idea that the popular will is vacillating, and still less to the theory that the decisive vote is that of the man who changes his opinion at almost every election—" the political animal with a nose for the winning side." The number of those who vote Liberal at one election and Conservative at another is demonstrably small. It is, of course, quite impossible to work out the figures, but the weathercock elector is probably not one in fifty of the total poll. These bugbears of the election agent are not, from the point of view of the candidate, numerous enough to worry about. They may win or lose a seat here or there where opinion is very equally divided; but the actual turnover of votes appears to be so small that it cannot affect the result of a general election.

The man who sometimes votes and sometimes abstains is far more important, simply because he is far more numerous—so numerous, indeed, that his vote or abstention has decided the fate of many governments. It is clearly conceivable that a minority of voters may sometimes win an election. Without allowing for uncontested seats, the total Liberal vote in 1885 was not half the electorate, yet they won; the total Conservative vote in 1895 and 1900 was even less, yet they won. Allowing for uncontested seats, the Liberals in 1885 and the Conservatives in 1895 and 1900 would probably have polled between 50 and 60 per cent. of the total electorate.

But this is not a valid argument against " the will of the people." The man who lets judgment go against him by consent in the law courts is not an argument against the administration of justice; and the man who is not sufficiently interested in politics to go to the poll cannot complain if he is governed by a minority. He has tacitly contracted out of the general will.

This abstention is far more marked in matters of local government than in parliamentary elections. In the latter case the voting varies, in contested seats, from 60 to 90 per cent. of the total electorate, which is practically the largest possible poll; the odd 10 per cent. of abstentions being accounted for by old age, illness or death, or unavoidable absence. For local government the voting varies from 30 to 50 per cent. in London County Council elections; in some other county or local elections the percentage is considerably less. In local government, therefore, a passive majority is ruled by an active minority—in parliamentary elections on the whole the majority rules.

The reason is simple. The issues at local elections are often unimportant, and evoke little interest, and people will not take the trouble to understand them. When the issues are important and rival policies are in sharp conflict—as in the Progressive-

Moderate feud in the London County Council twenty years ago —interest creates enthusiasm, and there is no difficulty in getting the voter to the poll.

The conclusion seems inevitable. All government rests on the consent of the governed; but autocratic rule depends on the passive consent, parliamentary rule on the active consent, of the governed. The latter system therefore assumes that every elector is not only able, but willing to, exercise his function of choice. When the bulk of the electors do so, the Government may be good or bad, but it approximates to the ideal of parliamentary rule; when only a minority trouble to vote, as in local elections, Local Government tends to approximate in fact, although not in theory, more nearly to the autocratic ideal, and the few rule the many.

The proportion of voters who go to the poll is a roughly accurate index to the amount of interest in the issues raised. But this in turn involves consideration of the difficult and complex question of the factors that make and alter public opinion —which exists and functions under both autocratic and parliamentary government—the examination of which must be deferred to a subsequent issue.

**Sir Patrick Manson.**

Sir Patrick Manson was the son of Mr. John Manson, of Aberdeenshire; was born on October 3, 1844; was educated at Edinburgh and at Aberdeen; and graduated in 1865 and took his M.D. in the following year. He appears to have commenced medical practice in the island of Formosa, from which he went to Amoy in China and then to Hong-Kong. He returned finally to England in 1890 and took up consulting practice in tropical medicine in Queen Anne Street, Cavendish Square. He was appointed one of the physicians to the Branch Seamen's Hospital at the Royal Albert Dock in 1894, and Medical Adviser to the Colonial Office in 1897; was made K.C.M.G. in 1903 and G.C.M.G. in 1912, when he retired from active practice. His death occurred on April 9, 1922, and a funeral service in his honour was held on April 12 at St. Paul's Cathedral.

When he was in Amoy Manson began to take great interest in tropical parasitology, and it was his work in this line which gave him his high position in the medical world, probably second only in Britain to Lord Lister and Sir David Bruce, if that, in modern times. The diseases with which his name was first associated were the group of maladies due to the nematode worm called *Filaria bancrofti*. This little creature, about the thickness of a thread of cotton but several inches long, lives in the lymphatic ducts, where it emits numbers of embryos which find their way into the circulating blood, in which they can easily be detected by the microscope. Owing to the plugging of the lymphatics by the parent worm numerous lesions are or may be set up, some of which are known as that hideous deformity called elephantiasis, while others are familiar to medical men under various names. Manson's work upon the pathogenesis of these diseases probably constitutes his greatest achievement, though he seems to have been partially preceded by other observers in this line (I have not studied the matter historically to a sufficient degree to give my opinion on matters of priority here). What brought fame to him was his hypothesis that these filariæ may be carried out of the human blood by means of mosquitoes. This notion was bitterly opposed—Heaven knows why, because at that time the great continental parasitologists had proved the law of metaxeny, according to which a species of parasite can occupy alternate hosts, and had already given many examples in which the law holds good, at least amongst the Metazoa. In or after 1858, Fedschenko, acting on Leuckart's suggestion, had shown that embryos of the *Filaria medinensis* of men, when emitted into water, attack and enter certain species of *Cyclops*. Manson, who was aware of this law, evidently concluded that a similar metaxeny probably occurred with the *F. bancrofti* and mosquitoes. In the *Lancet* of January 12, 1878, Cobbold mentioned a suggestion of Bancroft himself dated April 20, 1877, that *F. bancrofti* may be so carried, but at the same time stated that Manson had actually proved the first steps of the transformation. I have not been able to ascertain whether the original suggestion came from Manson or from Bancroft, but really the whole matter was a development of the previous work of the parasitologists. The arguments which led Manson first to conjecture that the mosquito is the host of the *F. bancrofti* were both sound and profound, but were of the same class as the inductions employed by Küchenmeister and Leuckart; and the stages of the life-cycle of *F. bancrofti* in mosquitoes which he subsequently found were very closely similar to those of *F. medinensis* in *Cyclops*. Both Fedschenko and Manson carried the development only to a short stage. It is remarkable that at that time and until my malaria work of 1898 Manson thought and taught that mosquitoes suck blood only once, and die in four or five days afterwards on the surface of water in which they have laid their eggs—although really the full development of *F. bancrofti* in them takes several weeks; and this extraordinary error prevented his tracing the young filariæ into the mosquito's proboscis, as was done later after my malaria work, and it vitiated his conclusions. Nevertheless we, who do so little to support our genuine investigators, should be duly thankful to his memory for what he did.

After he had returned to England Mr. H. G. Plimmer showed him the parasites of malaria (about 1894, I think). At that time I had been working on malaria for some years in India with the view of finding how the disease is communicated to men. Malaria is caused by the parasites called *Plasmodium*, discovered by A. Laveran in 1880; but I had failed to find them in cases in India owing largely to certain mistakes made there by various observers regarding them. In 1894 I came home on leave, and Manson demonstrated the true parasites to me in London. These organisms undergo a remarkable change when the blood containing them is drawn from the patient's finger, and only then. Near the end of 1894 Manson, whom I was then frequently seeing, informed me that he had just conjectured that this change was meant by nature to occur in the stomach of mosquitoes—a theoretical induction which had escaped Laveran and all other observers.

It should be clearly explained, in view of many statements frequently made, that the mosquito theory of malaria was not originated by Manson but is a very old one, dating possibly from the time of the Romans and certainly mooted much more recently by King in America in 1883, by Laveran in 1883, and by Koch in 1884, ten years before Manson thought of the same thing. But the argument for the theory which Manson gave was a very powerful addition to those previously employed; and I therefore determined to test the matter by experiment on my return to India in 1895. Manson's induction was one of the profoundest ever made in medical science; but it indicated only some suctorial insect as the carrying agent of malaria, and gave us no clue as to how or where the parasites live in that carrying agent, nor what its species might be. There are many hundreds of kinds of mosquitoes, and it does not follow at all that the malaria-bearing species is most prevalent even in the most malarious spots, while, at the same time, the task of determining the development of these minute unicellular parasites in mosquitoes was far more difficult than that of tracing the development of large worms in the same or in other insects. This work occupied me for four years of severe labour, chiefly owing to official interruptions of my work on three occasions. I first found the human malaria parasites growing in the *Anopheles* mosquito on August 20, 1897, and could have proved the whole life-cycle then but for an interruption of five months. My researches were communicated to Manson in a series of 110 letters, and were published in official reports and in the *British Medical Journal* by him and by me. My work was bitterly opposed just as Manson's work on *Filariæ bancrofti* had been, and was not generally accepted until it had been pirated by certain Italian writers in 1898–9. By that time I had infected numbers of healthy birds by bites of mosquitoes, and the Italians subsequently claimed to have infected three men in Rome in a similar manner; while the life-history of the *Plasmodium* in mosquitoes had been fully worked out by me and then by the Italians. In my paper on the *Cultivation of Proteosoma in Grey Mosquitoes* (1898) I gave Manson the full credit of my work up to that time, especially because he was then being violently attacked in the Medical Press for another matter.

Unfortunately, however, Manson's conjectures were sound only up to the point mentioned above, that some suctorial insect carries the *Plasmodium*. After that he plunged into a hypothesis which was quite erroneous, which led me wrong, which I was soon obliged to abandon, and which was finally disproved by MacCallum in 1897. Here again, as so often before, the working hypothesis proved to be nothing but a clue which frequently breaks in the hand; and, though the medical profession does not easily understand the difference, a conjecture, however plausible, is very far indeed from an established theory. I have always been surprised that Manson made no attempt to work out his own hypothesis for himself at the Royal Albert Docks in London, where he had as much material, both malaria cases and mosquitoes, as I often possessed in India. I urged him at least twice to do so; and before I left London in 1895 begged him to use malaria-infected birds for the purpose. He gave or procured for me little information about mosquitoes and his technique for *Filaria bancrofti* was much too coarse for the delicate malaria work. The whole life-cycle of the *Plasmodia* in mosquitoes was established by me before August 1898—the first case of metaxeny in *Protozoa*. I returned to England in February 1899, and spent much of the succeeding years in visits to Africa, Ismailia, Panama, Greece, Mauritius, and Cyprus in order to perfect and stimulate malaria-reduction by the methods of mosquito-reduction first fully described by me in 1899 (*British Medical Journal*).

In 1898, largely in consequence of my malaria work, Manson persuaded Mr. Joseph Chamberlain, then Secretary of State for the Colonies, to recommend the establishment of Schools of Tropical Medicine. They should really have founded a Colonial Office School on the model of the Netley School of the War Office and India Office; but, instead of that found it cheaper to get the thing done by voluntary subscriptions. This of course meant that the teachers were the sufferers, as I myself can testify from my experiences at Liverpool—small salaries and no pensions. But it was a good stroke of business on the part of the Colonial Office, which not only got its doctors taught the elements of tropical medicine for almost nothing at our expense, but obtained numerous malaria surveys and scientific expeditions to Africa and elsewhere for as little expenditure. Small gratitude has it shown for the work. Manson's school in London was chiefly a teaching centre; but we in Liverpool made most of the surveys and certainly inaugurated the methods of malaria reduction which were subsequently carried out properly by the Americans at Havana and Panama, and by Malcolm Watson in the Federated Malay States—perhaps the greatest advance in tropical sanitation ever made.

Manson was a parasitologist and a doctor, not a sanitarian. I do not think that he ever attempted to apply his filaria-mosquito work for the practical reduction of filariasis. When I commenced mosquito reduction in Sierra Leone in 1901 he, like many other doctors and biologists, was astonished and even alarmed, and, contrary to statements which have been made, did not in any way originate or assist that advance. When I was begging for practical measures in Sierra Leone in 1900 he spent money on keeping two or three gentlemen in a mosquito-proof house in the Campagna for a few months in order to provide an additional proof of the mosquito-theory of malaria—which had been already proved ![1] How far he was responsible for the failure of the Colonial Office and other British Government departments as regards malaria-prevention (see SCIENCE PROGRESS No. 56, p. 664, April 1920), I cannot say; but neither Sir William MacGregor nor I could get a hearing there on that matter. I think, however, that Manson's duties concerned only medical cases.

He suffered much from *claqueurs*, who in puffing him and incidentally themselves and their institution caused considerable offence among those who knew the facts; and there was a disagreeable affair at the Royal Society in consequence, in 1905. I see that the same gentlemen are still repeating the same absurdities in the numerous obituaries which have appeared—not one of which, even in the medical or scientific press, has been quite accurate. It is shameful that obituary notices should be exploited in this manner, and I am glad to see that Sir Ray Lankester called attention to the point in *Nature* for April 29, 1922. It is not true, as stated in the *Lancet*, April 15, 1922, that Manson "was the first to trace the connection between the mosquito and the malaria parasite": and Colonel W. G. King has already pointed out (*Nature*, May 20, 1922) that "the work of Ross proved Manson's theories in essential details incorrect and misleading." An exact statement of the facts will be found in my *Prevention of Malaria*.

Most of Manson's guesses, such as those regarding sleeping sickness and yellow fever, were not as fortunate as his induction regarding malaria. Genuine science rightly refuses to allot much or any credit to arm-chair speculations by those who do not undertake the labour and expense of testing them, but afterwards try to claim discoveries on the strength of them. Manson himself did not make this mistake, but modern "medical science" is full of *poseurs* who do—see, for instance, the absurd letter by L. W. Sambon in *Nature*, May 27, 1922.

But in spite of his friends Manson was a great man. A grave and impressive teacher, he exerted profound influence over young men, and his literary style was so excellent that his published papers and books are not only full of facts and ideas, but are as interesting as any histories can be. These are common virtues; but his parasitological studies lifted him above the sphere of the doctor and the teacher into that of the discoverer. In my opinion he was never adequately treated by his countrymen. Long before he retired he ought to have been placed by them in a position of independence in which he could have devoted the remainder of his life to the investigations which he loved.

RONALD ROSS.

[1] He consulted me on this matter beforehand. I told him that it would provide no proof at all. He admitted this, but said that it would be a good *advertisement* of the theory. It is now impudently vaunted even in the medical press as the final *proof* of the theory! No one can accept this who knows anything about either malaria or the nature of scientific proof.

**Dr. Henry Lyster Jameson.**

We regret to announce the death of Dr. Henry Lyster Jameson, at his residence in West Mersea, on Sunday, February 26. Jameson was a very accomplished zoologist and also an acute and capable administrator. As a boy he went to sea before the mast, and after "roughing it" in this way he received his scientific education at Trinity College, Dublin, where he took the degree of M.A. He spent a year at the Royal College of Science in London, and then two years at the University of Heidelberg, where he took the degree of Ph.D. Then he went to Samarai in British New Guinea, where he had charge of a pearling station and had opportunities for much zoological research, the result of which was a revision of the pearl-shells and a study of the processes involved in pearl formation. Returning to England, he was, for a time, lecturer at the Municipal Technical College at Derby, and there and at the Lancashire Fisheries Station, at Piel, Barrow-in-Furness, he demonstrated in a very brilliant manner the parasitic theory of pearl formation in the common sea mussel. About this time his health broke down and he had to go to South Africa, where he was, for a time, an inspector in the Natal Educational Department, and then a lecturer at the Technical College in Johannesburg. He and his wife spent much time in collecting in the Transvaal. Again returning to England, he was given an administrative post in the Board of Education, but at the outbreak of the war he was seconded for special fishery work with the Ministry of Agriculture and Fisheries. He was District Inspector for the South-East Coast, and he also established a very successful shell-grit factory at West Mersea, which utilised waste material collected by the local oyster dredgers. For the last three years of his life he was also adviser on Inshore Fisheries to the Development Commissioners.

Since 1901 he lived in a continual state of ill-health which had, however, no apparent effect on his activities. He did brilliant work on pearl formation and became the leading authority on this subject, but his administrative work, at the Board of Education, in the Ministry of Agriculture and Fisheries, and at the Development Commission was of a very high order: he showed that a man who was by nature a field zoologist and able to practise scientific technique of the best kind could also be an exceptionally capable administrator. In spite of chronic bronchitis, emphysema, and a dilated heart, he went about a great deal even in 1919, going to sea on the West Coast of Scotland to report on the possibility of establishing oyster fisheries in the lochs. He worked very quickly and could make rapid but eminently sound decisions.

Of late years an interest in all kinds of economic reform became almost a passion with him: that a man of his keen insight and high intellectual grade could identify himself with extreme Labour politics had a powerful effect upon his many friends, and it was extraordinary to note the influence he had on all sorts of people. He was a brilliant conversationalist and a maker of striking epigrams. He feared nothing so much as a condition of chronic invalidism, so that his death, coming suddenly as it did, was a happy fate. There are few scientific men whose loss will be so grievously felt by their friends. His career will be a conspicuous example of the success with which a man of high scientific attainments can also act as an administrative official.

**Death of Two Well-known Physiologists.**

We have to record the death of Prof. Augustus Waller, the well-known physiologist, who died at the age of sixty-six. Prof. Waller's death will come as a shock to many of those who knew him personally and believed that he had many years of fruitful work before him.

Waller was a student of the Universities of Aberdeen and Edinburgh, and he also studied in Germany. He subsequently held a number of positions in London, and ultimately became Director of the Physiological Laboratory of the University of London. Prof. Waller was a very versatile physiologist, and had published nearly 200 articles: among Waller's best pieces of work was the development of the string galvanometer in connection with the clinical diagnosis of diseases of the heart. Waller became a Fellow of the Royal Society in 1892, and several foreign Academies recognised his work by the award of various honours. Prof. Waller was exceedingly impetuous and extraordinarily energetic in the pursuit of what he believed to be a scientific truth, and his extreme keenness brought upon him occasional criticism, but remembering the pureness and truth of his scientific quest and disputation, his friends, of whom he had very many, understood him and overlooked his rashness.

Prof. Waller leaves a widow and two sons, and all those who knew Prof. Waller will extend to Mrs. Waller and her children their warmest sympathy in their sad loss.

Prof. Benjamin Moore died of appendicitis at the age of fifty-five. He was born in Belfast, and was first of all an engineer; but he later went to Germany and studied physical chemistry in Ostwald's Laboratory. He afterwards worked with Sharpey-Schafer in London. He was subsequently appointed to a Chair of Physiology at Yale Medical College, where he worked for some years. He returned from Yale to the Charing Cross Medical School, where he lectured in Physiology, and at the same time took a degree in medicine; subsequently he was elected to a Chair of Biochemistry at Liverpool. During the war he did excellent service in the Department of Applied Physiology, and in 1918 was elected to the Whitley Chair of Biochemistry at Oxford.

Benjamin Moore had an extraordinary career; he was a man of brilliant imagination and great enthusiasm. It was Moore who showed that, in munition factories, tri-nitro-toluene poisoning was caused mainly by absorption of the poison through the skin, a result which was at first keenly disputed. But it was this discovery which enabled proper precautions to be taken against this form of poisoning.

### Organic Evolution according to Major L. Darwin.

Major Leonard Darwin has lately published a small book on Organic Evolution dealing with its outstanding difficulties and their possible explanations. The contents of this publication is divided into six sections as follows:—

1. The selection of infrequent mutations and the inheritance of acquired characters could not alone account for evolution.
2. To admit the selection of small and frequent mutations amongst the explanations of evolution demands the solution of several unsolved problems.
3. The existence of a system of mutations due to imperfect segregation is suggested as one of the possible explanations.
4. The problems to be solved include the appearance of new forms and the bifurcation of species.
5. In fertility between species, the facts connected with pure lines have also to be explained.
6. In experiments designed to test this hypothesis, natural conditions should be imitated.

Major Darwin states that recently there has been a growing belief in the efficacy of the inheritance of acquired characters, and in the direct effects of environment as factors in evolution, these being agencies on which Charles Darwin relied to some extent. Major Darwin himself maintains that standing alone they cannot account for evolution, even if this tendency to revert to Charles Darwin's views should prove to be thoroughly justifiable.

Then, as to large mutations, even though it may be right to include them amongst the evolutionary agencies, yet they cannot be relied on to fill the gap left in the explanation of the origin of existing organisms. The author states that we must rely in a measure on small and frequent mutations, or admit that no explanation is now forthcoming ; and certainly it was on the natural selection of such mutations that Charles Darwin made the greatest stress. The difficulty of proving the existence of small mutations has led certain experts to deny their existence, but the smaller the mutation, the more difficult does it become to prove its presence ; and to assume that minute mutations are constantly occurring is a legitimate hypothesis, if it best fits in with all known facts. The main difficulty in the theory of organic evolution are how to explain the uniformity of useless characters, the adaptation of structure to environment, and the originating of specific differences ; and it seems that all these difficulties are to a large extent overcome if the hypothesis of small and frequent mutations may be accepted.

Major Darwin, whose book has been published by the Cambridge Press, has contributed an article of much value to the study of organic evolution.

**Report of the Royal Commission of the Universities of Oxford and Cambridge.**

The report of the Royal Commission of the Universities of Oxford and Cambridge may be procured in the form of a Blue Book price 6*s*. This Commission has been sitting since November 1919, under the chairmanship of Mr. H. H. Asquith. The report will be read with interest by members not only of the older Universities, but also by the Staff of other Universities in various parts of the British Empire.

The Commission started out with the premise that one of the most important functions of a University is the pursuit of Research Work. Their first consideration is with regard to the extraordinary increase in numbers of students in both Oxford and Cambridge ; this of course applies to all the Universities in the British Empire. The report says that either (*a*) the number of students must be decreased ; or (*b*) the staffs must be increased ; or (*c*) the standard of learning must be allowed to go down.

The Commission, believing that disinterested pursuit of scientific investigation affords the surest method by which the nation can ultimately command the resources of Nature, nevertheless makes certain recommendations whereby a closer relation may be developed between science and national development. The report recommends that each University receive, instead of the existing interim grant of £30,000, an annual grant of £100,000, in addition to £10,000 a year for women's education and extramural work, and a lump sum for pension arrears.

With regard to the question of College Fellowships, the Commissioners recommend that these be divided into the following classes : (*a*) Restricted to those who hold certain University posts ; (*b*) Fellowships associated with official posts in the college, or with University Lectureships or Demonstratorships ; (*c*) Old Fellows who have retired from active work ; (*d*) Fellowships to which young graduates may be elected under conditions of research ; and (*e*) Supernumerary Fellowships.

With regard to payment of these fellowships, the Commission recommends that only (*b*) and (*d*) should be stipendiary. If this recommendation is carried out it will do away with the horde of college " hangers-on " and parasites.

With regard to the matter of Pensions, the report recommends that the federated superannuation system of the Universities be adopted.

Finally it is recommended that the money procured through the State for college or University staffs be used to ensure more time for research, and not for the teaching of the students.

**Notes and News.**

Among the names of notable men whose deaths have been announced during the past quarter we have noted the following: Sir Wm. P. Beale, lately Treasurer and President of the Mineralogical Society; Dr. J. F. Bottomley, of fused silica fame; Prof. W. B. Bottomley, Emeritus Professor of Botany, King's College, London; G. L. Ciamician, Professor of Chemistry at Bologna; Dr. H. N. Dickson, geographer and meteorologist; Sir Alfred Pearce Gould; Prof. P. A. Guye, the famous Swiss chemist; Camille Jordan, Professor of Mathematics at the École Polytechnic; Sir A. B. Kempe, Treasurer of the Royal Society 1898–1919; Prof. T. Liebisch, of the University of Berlin; Sir Patrick Manson; Dr. J. T. Merz, electrician and philosopher; Prof. B. Moore, Whitley Professor of Chemistry in the University of Oxford, and discoverer of the origin of T.N.T. poisoning; Prof. V. I. Palladin, botanist, University of Petrograd; Dr. Charles T. Waidner, Head of the Division of Heat and Thermometry of the Bureau of Standards, U.S.A.; Dr. A. D. Waller, Director of the Physiological Laboratory in the building of the University of London, South Kensington; Dr. G. V. Wendell, Professor of Physics at Columbia University.

Sir Ernest Rutherford has been nominated President of the British Association for the meeting to be held at Liverpool next year.

Prof. A. S. Eddington has been elected President of the Royal Astronomical Society; Sir Frank Dyson President of the Optical Society; and Dr. C. Chree President of the Royal Meteorological Society.

The Founder's medal of the Royal Geographical Society has been awarded, this year, to Col. C. K. Howard-Bury for his work in command of the Mount Everest Expedition last year; the Patron's medal goes to Mr. E. de K. Leffingwell for his investigations on the coast of Northern Alaska.

Mme Curie has been elected Associate Member of the French Academy.

Mr. W. W. Smith succeeds Sir J. Bayley Balfour as Regius Keeper of the Royal Botanic Gardens, Edinburgh.

Prof. W. Nernst is to combine his duties as Rector of the University of Berlin with the directorship of the Physikalisch-Technische Reichsanstalt.

Sir Charles Parsons has given £10,000 to the Trustees of the British Association.

Prof. R. A. Millikan is now Director of the new Norman Bridge Laboratory of Physics of the California Institute of Technology at Pasadena. The Laboratory is magnificently equipped for modern physical research, and includes a high-tension laboratory containing a million-volt transformer provided by the Southern California Edison Company. It is near the Gates Chemical Laboratory and Mount Wilson Observatory, and has ample supplies of hydroelectric power close to hand. It is evident that the California Institute will become one of the foremost centres of physical research in the world.

It was announced last February that the Rockefeller Foundation would provide 2,000,000 dollars towards the cost of building a State School of Hygiene in London. The offer was made on the understanding that the Government would provide for the staff and maintenance of the school when it is established, and we believe that £25,000 is to be granted annually for this purpose. The necessary buildings will probably be erected in close proximity to the new site for the Central Offices of the University of London. The Rockefeller Foundation has also allocated 6,000,000 dollars to the Johns Hopkins University for a similar purpose.

We have just received from Messrs. Macmillan & Co. a copy of the first volume of the *Dictionary of Applied Physics* edited by Sir R. T. Glazebrook (Vol. I, Mechanics–Engineering–Heat; price £3 3*s*. net). It will be reviewed in due course, but a brief inspection is sufficient to show that the book will become indispensable to all those whose work brings them into contact with problems of a physical character. The articles are of sufficient length to be really comprehensive, and the references show that the results of very recent research have been incorporated in them. The writers are without exception men of recognised reputation as theoretical or experimental physicists, and in most cases have an expert knowledge of the subjects on which they write. The publishers have done their share of the work most admirably and their enterprise deserves every possible success.

The Institute of Physics is collaborating with the National Physical Laboratory for the production of a *Journal of Scientific Instruments*. A preliminary number has been circulated in order to ascertain the amount of support such a journal is likely to obtain. No periodical of this type has heretofore been published in English, although a somewhat similar journal has appeared for some years in German, and in France another, dealing more particularly with optical instruments, has just been started. If a sufficient number of subscribers are forthcoming the journal will appear monthly, the subscription being 30*s*. per annum. Each number will contain thirty-two pages, and the editors ought to find little difficulty in filling these with articles of first-rate importance. It will be very disappointing if the support given to the Institute in this, its first, venture is inadequate, more especially as a similar publication is about to be started in the United States.

One of the features of scientific work in America is a craze for the invention of new units and the redefinition of old ones. A letter to *Science* from the Blue Hill Observatory, Harvard, gives some very necessary information as to the meaning of the Kelvin kilograd scale of temperature. If we follow this correctly it is designed to make the coefficient of expansion of air at constant pressure equal to ·001 instead of ·00366, and to this end the zero of the scale is taken at the absolute zero—273·12° Ac (? Absolute centigrade) and the "freezing-point of pure water at megabar pressure 1,000." The calorie is then defined as the quantity of heat required to raise the temperature of 1 gram of pure water from 1,000 to 1,003·66 Kelvin kilograds. It is claimed that this scale shortens calculations and is independent of that very variable quantity the boiling-point of water.

The Nobel Prize Address delivered by Max Planck before the Royal Swedish Academy of Sciences in June 1920, and entitled *The Origin and Development of the Quantum Theory*, has been translated by H. T. Clarke and L. Silberstein and may be obtained from the Clarendon Press (Oxford, price 3*s*. 6*d*. net). In twenty pages of large print it contains an historical survey of the development of the theory such as could only be given by one who had contributed largely to that development. In spite, however, of the absence of any mathematics, the lecture will only be appreciated properly by those already familiar with its subject.

We have received *Bulletins* No. 16 and 17 of the National Research Council of the United States. No. 16 is entitled *Research Laboratories in Industrial Establishments of the United States*, and is only of interest in this country as showing the enormous number of graduates in chemistry, physics, and engineering who find a place in American industry. Thus the Eastman Kodak Co. is returned as employing 46 chemists, physicists, and photographic experts with 60 assistants; du Pont, E. I., de Nemours & Co., 200 graduate chemists and engineers, while the Western Electric Co. return their research staff as approximately 825 physicists, chemists, and engineers, and 750 draughtsmen, assistants, etc., their laboratory being a thirteen-story building of 400,000 sq. feet floor area. Altogether 526 firms are returned as employing research staffs, though, of course, many of these are small consulting firms with works laboratories. *Bulletin* No. 17 contains an abstract of the papers presented before the second annual meeting of the American Geophysical Union held at Washington in April 1921. Twenty-three papers altogether were read; these being divided between the sections of Geodesy, Meteorology, Terrestrial Magnetism and Electricity, and Physical Oceanography. Taken together they present an admirable survey of the present positions of these branches of science. The first paper, by Lyman J. Briggs, describes the various appliances which have been devised for the measurement of gravity at sea, including that used by Duffield when travelling to Australia for the B.A. meeting in 1914. A paper by Dr. W. F. G. Swann deals with the penetrating radiation which would appear to exist at the earth's surface and to produce ions in the air at the rate of 4–6 per c.c. per second; while another, by C. F. Marvin, sounds a note of caution in drawing conclusions concerning any connection between solar activity and terrestrial weather.

Among a number of very interesting exhibits at the Royal Society Conversazione on May 17 was one illustrating a remarkable phenomenon discovered by Prof. H. B. Baker, F.R.S. It is found that when certain liquids (*e.g.* mercury, benzene, bromine, alcohol, ether, etc.) have been dried in the presence of phosphorus pentoxide for some years (7–9 in the cases dealt with) their boiling-points are very considerably higher than usual (from 26°–62° C. in the case of different liquids). This anomaly is probably due to association increasing the size of the molecules, since the surface tension of the liquids also becomes abnormally high.

The British Association has published a number of reprints of addresses and reports read at the Edinburgh meeting last year at prices varying from 9*d.* to 3*s.* 6*d.* We would particularly recommend to our readers No. 1, which contains the address on Science and Ethics delivered by Principal E. H. Griffiths.

Early in 1915 Mr. J. W. Robertson Scott set out for Japan in order to obtain data for a sociological book on small farming and rural life in Japan in the hope that it might provide some guidance towards our own agricultural reconstruction in post-war days. His residence in that country extended over four and a half years, two of which were spent in founding and editing a monthly review, *The New East,* whose purpose was to tell the Japanese something about their Western Ally and of the issues at stake in the war. In the rest Mr. Robertson Scott travelled some 6,000 miles in the rural parts mixing and talking with all classes from farm labourers to Ministers of State. The result of his researches is before us in a book entitled *The Foundations of Japan* (John Murray, 24*s.* net), which presents in an attractively readable form an enormous amount of information concerning the methods, habits, and outlook of the dwellers in the Japanese country-side—a class little known in England, although it forms more than half the population of the whole country.

We note from a statement in the March number of the *Radio Review* that the continued high cost of printing has made it necessary to suspend the publication of that journal. Arrangements have been made to devote a few pages of the *Wireless World* to research articles such as have been appearing in the Review. It is to be hoped that this suspension will not be long continued; under the direction of Prof. Howe and Mr. Coursey the Review has maintained a high standard, and its disappearance will be greatly regretted by those interested in mathematical and commercial wireless design.

In the *Proceedings of the Royal Society of Medicine,* 1922, Dr. W. Broughton Allcock and Prof. J. G. Thomson have contributed an article on the sporozoon *Eimeria oxyspora,* Dobell. This is the second occurrence of a specimen from human fæces in England. It has only once previously been found, by Dobell in 1919, but Thomson's patient had been to the Continent and Malta; in this paper will be found some excellent drawings by Dr. A. Robinson of cyst spores of *Eimeria.*

In the *New Zealand Journal of Science and Technology,* June 1921, Mr.

W. J. Phillipps, of the Dominion Museum, gives a list of the chief food fish of New Zealand, with some information in each case as to distribution, spawning season, etc., which should prove of interest to those interested in fisheries.

In the *Memoirs of the Indian Museum*, Vol. V, 1921, A. Tokio Kaburaki describes a number of new leeches from Lake Chilka. The following genera are represented: Piscicola (2), Pterobdella, Glossosiphonia and Limnatis (1 each).

In the *Annals of the Durban Museum*, Mr. L. F. Spath has given a list of the Upper Cretaceous Ammonoidea from Pondoland which should prove of interest to those concerned with the geology of South Africa.

A complete list of the Butterflies of Trinidad has now been made by Mr. William J. Kaye and is on sale at the Department of Agriculture, Trinidad, B.W.I.

The question of Charcot-Leyden crystals is still shrouded in mystery, and it is evident that a considerable amount of work still remains to be done in making clear their exact significance. Dr. J. G. Thomson considers that these crystals are probably the result of cytolytic action of *Entamœba histolytica* on the body cells. Dr. Thomson finds that Charcot-Leyden crystals are present in a very high percentage of cases of amœbic dysentery, and are most commonly present when the disease is of long standing; the presence of Charcot-Leyden crystals in human stools is diagnostic of amœbic colitis due to *Entamœba histolytica*. (See *Proceedings of the Royal Society of Medicine*, 1921.)

*Nature* of March 9, 1922, contains an article by Dr. J. A. Murray, of the Imperial Cancer Research Bureau, on Cancer Research. He says that the search for the cause of cancer in the form of a developmental abnormality does not appear to command many followers. Apparently, even though cancer research work is now widespread, the progress towards the elucidation of the cause of this dreadful disease has not gone step by step with the amount of material and time spent on this investigation. He says research into the treatment of cancer, other than surgical, has produced many empirical experiments and observations, but apart from the extended knowledge of radiotherapy, nothing of importance has come to light: he concludes that it may be predicted that progress in cancer research will in large measure be closely co-ordinated with that of the ancillary sciences.

Some interesting work is being carried out by Dr. H. S. Wardlaw, of the University of Sydney, into the diet of Australians. The latter are people of British origin adapting themselves to a new environment. Few of them can claim an Australian descent of more than two generations. Yet many of their customs already show a marked divergence from those of the parent countries; we trust that Dr. Wardlaw will continue his work in this field.

*A Manual of Meteorology*, Part 4 (Cambridge University Press), by Sir Napier Shaw, has come into our hands. This section is on the relation of the wind to distribution of barometric pressure. Within the past four years urgent questions have been addressed to the Meteorological Office from many quarters about the winds. The work of the Meteorological Office, aided by the contributions from various departments of the Naval, Military, and Air Services, has provided the material for answers to these questions. The object of this book is to present a summary of all the sources of reference in a handy form for conveying an idea of the information which is available. Sir Napier is to be congratulated on contributing such an important work on the dynamics of meteorology.

During the war a considerable amount of work was carried out by English and French protozoologists on Amœbic Dysentery; in later stages of the war certain American protozoologists took up the subject, and the

*Archives of Internal Medicine of America*, 1919, contains a paper by Kofoid, Kornhauser, and Miss Swezy on criterions for distinguishing the various types of entamœba. A table has been provided giving a key which enables one to distinguish between the various types; this paper has been partly compiled on the work of Dobell, Jepps, Matthews, and Smith.

The *Quarterly Journal of Microscopical Science*, Part 4, 1921, contains an interesting paper by Prof. Champy, of Paris, and Mr. Carleton, of Oxford, on the shape of the nucleus: these workers consider that the following factors are responsible for the varying shapes of the nucleus in different cells: (1) Surface tension; (2) mechanical deformations; (3) the presence of the Centrosome; (4) general shape of the cytoplasm; and finally the presence or absence of various canaliculi and incisions in the nuclear membrane, or of the presence of intranuclear rodlets.

The *Philosophical Transactions of the Royal Society*, 1920, contains a paper by Prof. O'Donoghue on the Blood Vascular System of Sphenodon. The author comes to the conclusion that Sphenodon approaches the Lacertilia more closely than any other order of the Reptilia, but that it nevertheless differs from them to such an extent that Günther was thoroughly justified in placing it in a separate order.

Prof. Arthur Dendy, of King's College, London, has recently produced a monumental report on the Sigmatotetraxonida collected by H.M.S. *Sealark* in the Indian Ocean. The scope of the suborder Sigmatotetraxonida is greatly enlarged by the author's inclusion therein of the Lithistidæ and Clavulidæ, and the group as now constituted is by far the largest of the tetraxonid suborders, being represented in the *Sealark* collection by no fewer than 125 species. Of this total 57 species are here described as new, 6 are identified with previously known species (in some cases as new varieties), and 4 are identified generically only.

Prof. Dendy has studied the spicules of the Tetraxonida very carefully, and has been able to trace out in a remarkable manner the metamorphosis of various straight, sigmoid, and granular spicules from an original Tetraxonida type. It has been shown that a straight spicule occurring in a number of groups of sponges is not necessarily a homologous structure in each group, but in some cases, as in the Tetraxonids, certain straight spicules have been derived from the tetraxonic type by a process of elongation of one axis and the reduction of others.

The question of the double innervation of striated muscle has come to special prominence within recent years. It is a well-known fact that ordinary skeletal muscle is provided with both sensory and motor nerve-endings. But in addition it has been shown by some workers that what seems to be a third type of nerve-ending can be demonstrated. Some authorities have suggested that this third type of nerve-ending is connected with the sympathetic nervous system. In many cases a fine non-medullated fibre can be seen to accompany a medullated fibre, the medullated fibre being either sensory or motor, the non-medullated fibre being possibly the so-called sympathetic structure. Prof. J. T. Wilson in *Brain*, 1921, gives a review of the evidence on this subject, and considers that so far no satisfactory proof has been provided of a dual system of innervating motor fibres. With regard to the question of tonus and the sympathetic nervous system, Kuno, working in Starling's laboratory at University College, London, did not find any diminution of tonus after extirpation of the sympathetic or after section of the rami communicantes. Prof. Wilson considers it is difficult, if not impossible, to avoid the conclusion that the accessory or tertiary fibres are sympathetic in origin.

# CORRESPONDENCE

To the Editor of "Science Progress"

## THE MENTAL ABILITY OF THE QUAKERS

From John W. Graham, M.A., Principal of Dalton Hall, Manchester

Dear Sir,—Dr. Hankin of Agra writes in your April number an article with the above title, expounding the achievements of Friends, and contrasting these with their queer doctrines and practices. He says that they are a small "sect of religious fanatics," dreading "sensible reasoning as a temptation of the Evil One," and chiefly concerned with the "plain" language, a curious dress, an education in which the training of intelligence is subordinated to dogma and formality, and a testimony for Peace which Dr. Hankin misrepresents.

The contrast thus drawn is indeed puzzling. But it is all due, put bluntly, to lack of knowledge of the subject. The writer seems to have worked at the Society's Library in London and collected his personal data there, so it is very strange that he should never have discovered what Quakerism is all about. There are many books upon it in that Library.[1] He quotes instead the twisted conclusions of Macaulay, of all writers, for information. No historian would have done so, on this subject; for were not Quakers friendly to James II? George Fox's occasionally preposterous Scriptural arguments were what his Puritan and Anglican judges and persecutors believed in; and he with them, but far less completely. The strength of George Fox was in placing inward conviction above the letter of the Bible. Quakers are, briefly put, rational Mystics, and Christians of the primitive type, rejecting clergy, sacraments, and all ritual.

The strength of Friends, in business, philanthropy, banking, science, and invention, as described in the Essay, has lain in their reverence for human beings, as the only holy Temples where the Divine dwells. Everything that they believe, even the temporary fads about dress and speech now abandoned, grew out of this. It led them to adopt their just, industrious, self-reliant ways, to preserve their openness of mind and willingness to learn, and their aloofness from dogma. They were spared the expenses due to fashion, to self-indulgence and to ecclesiastical establishments. Such people saved money.

Then they were excluded from some professions. The Church, the Army, the Navy, and Government employment were barred. So were Oxford and Cambridge till 1873. An artistic or musical career was discouraged in the puritanic period, say to about 1850. There were left Law, Medicine, Teaching, Farming, and Business. On these they concentrated. The last fitted best with intelligent people deprived of a University education. Honesty, good judgment, and accumulation produced the Quaker banker.

[1] May I perhaps venture to refer him to one of my own, *The Faith of a Quaker*, published by the Cambridge University Press in 1920, and therefore recent?

One of the oddest of the remarks in this article is that the power of money-making came at or soon after conversion. The article is full of cases to the contrary where money was not made till the third or fourth generation. It is true that not many men already rich joined Friends.

The really instructive fact which Dr. Hankin might have brought out, if he had known it, is that these wealthy families nearly all leave the Society in time, and join the Church. Quakerism may lead to wealth, but wealth does not agree easily with Quakerism. Only the recently wealthy names in his list are still counted among us to any extent.

The contrast drawn by Dr. Hankin with the Mennonites is, I believe, real, but left unexplained. These excellent people are, when not persecuted, diligent and frugal and well-to-do, chiefly farmers. They are faithful followers of Scripture rather than rational Mystics, and so have never developed on intellectual lines as Friends have, nor mixed gladly with the world of thought. This would be my explanation of the difference noted.

John W. Graham.

Dalton Hall, University of Manchester.

# ESSAY-REVIEW

**THE PHILOSOPHY OF PHYSICS.** By Prof. A. W. Porter, D.Sc., F.R.S., being a review of **Physics: The Elements.** By Norman Robert Campbell, Sc.D., F.Inst.P. [Pp. ix + 565.] (Cambridge, at the University Press, 1920. Price 40*s*. net.)

" It is not the facts but the explanation of them that matters." Such is the motto which precedes the preface to this book. The subject-matter has been accumulating since 1904: first of all in the form of separate essays (some of which have already appeared in print). In 1919 an attempt was made at co-ordination, but this met with difficulties. " I found that I had forgotten about the matter so completely that, at the outset, the manuscript might have been that of an unknown author. It would have been wiser to read it, burn it, and start afresh." This was not done, however. " The co-ordination of the separate essays is still incomplete, and there are several instances where the point of view is rather different in different parts of the book." " The other fault is a complete lack of reference to the works of others."

The book is primarily intended to meet the needs of professional physicists. It assumes throughout entire familiarity with all the facts and theories of physics, ancient and modern. Its object is not to add to scientific facts. " Briefly, it may be said that what is aimed at is not investigation or exposition, but criticism." " Criticism of this nature has secured a large part of the attention of pure mathematicians for the last thirty years, and has become almost a new branch of their study. In this treatise on physics I hope to extend in some measure such criticism to a portion of experimental science."

Thus far, we have allowed the author to speak for himself. He is aware that his is not the first attempt. Reference is made to Poincaré, whose essays abound in criticism of the fundamental conceptions of physics. But others have also ventured on the same ground—mention may be made of Kirchhoff, W. K. Clifford, Mach, Karl Pearson, Hertz; while we leave unmentioned the large number who, though adequately trained in the laws of thought, have not had the equipment necessary on the physical side.

The range of the book can to some extent be gathered from the titles of the chapters. From Part I we select: The nature of laws, The explanation of laws, Theories, Chance and probability, The meaning of science; and from Part II, Fundamental measurement, Physical number, Numerical laws and derived magnitudes, Units and dimensions, Errors of measurement, Mathematical physics. It is impossible in a short review to do more than select, almost at random, one or two cases for special consideration. There is more suitability in such a random selection, because the author's own illustrative cases often seem to have the same character. One of the chief faults we have to find is the lack of orderly development of the subject.

To illustrate the author's methods take first the consideration (p. 40) of Hooke's law, " stated in the form that the extension of a body is proportional to the force acting upon it." This is the first example of a physical law considered in detail, and is given to illustrate the complexity of laws. Emphasis is laid upon the numerous other laws which may be involved in its verification. To measure the extension, often very small, we may use an optical lever involving the laws of reflection of light or a level and micrometer screw. It may be urged that such experimental devices are merely a matter of convenience. The truth of Hooke's law does not depend upon the laws of reflection of light; if there were any doubt about these laws, we could adopt another method which does not involve them. Campbell urges, however, that if we confine ourselves to the only direct method, involving merely a millimetre scale, the scope of the law will be very much restricted (owing to the smallness of the extension ?). Indirect methods are therefore necessary involving other laws. "But there is one law common to them all, namely that they all give the same result." He therefore concludes that "it seems impossible to accept the view that the laws involved in the use of experimental devices are in no way essential to the laws which they are employed to prove; it seems to be indicated that a law, namely that different methods of measurement agree, is involved in the use of the term 'extension.'" He then considers the conception of force, defining it as the product of mass into acceleration, in illustration of a similar complexity. This example is so characteristic of the general nature of the book that a few comments on it are desirable. We are suddenly plunged into the middle of a complex phenomenon. It is impossible to speak rationally of extension and force until these have been defined. To urge this in a three-page argument may be appropriate enough in explaining the matter to "a person of average intelligence, but wholly devoid of scientific knowledge—say, the minister in charge of a Government department." What the Government minister would make of the explanation we do not feel sure. He would probably go away thinking that science is not as straightforward as he has been asked to believe. When he meets with difficulties as to what force is, he is supposed to be told that it is mass multiplied into acceleration; but he is not told either what mass or acceleration is, nor even how you can multiply them together. No doubt these further explanations are supposed to be given in retrograde sequence as the minister drives his informant more and more into a corner. But the order seems to be curiously topsy-turvy in a book written specially for professional physicists and not for the instruction (or mystification) of departmental ministers.

We have chosen this example because it illustrates a disorderliness which it seems to us is characteristic of the whole book. We regret that space does not permit us to demonstrate this statement in detail.

There is also a tendency to push arguments up to a stage where they become fanciful. Thus (p. 50), he argues that all laws are connected, though in many cases the connection may be so slight as to become inappreciable. Thus Hooke's law involves the conception of force. But the force brought into play may, in a particular case, arise from the incidence of radiation (the "pressure of radiation"), and radiation is an electrodynamic phenomenon. Hence there is a connection between Hooke's law and any law in which the laws of electrodynamics are involved. And the author adds, "No doubt this conclusion seems fanciful, and it is not pretended that it is of the slightest importance in the practice of physical investigation." The general statement as to the interconnection between phenomena may be conceded, but the illustration seems a singularly unhappy one. The laws of electromagnetics might change so much that there was no pressure of radiation at all, and Hooke's law would not be in the slightest degree affected. What might be affected would be the connection between the extension and (say) the magnetic vector in the incident wave; but this connection is, of course, not Hooke's law. It may quite plausibly be regarded as one of the prime functions of the scientific investigator to seek out the quantities whose interconnections are of the most universal character. A perfectly correct "science" might be built up in which we connected extension (for example) successively with terrestrial position (gravitation), the magnetic or electric qualities of neighbouring objects, rotations (as when the rod is whirled round), etc. Each of these connections for its specification would require a knowledge of the "laws" governing the individual phenomena. Modern science proceeds, on the other hand, by inventing a quantity which it calls *force* by aid of which a relation can be specified which is common to them all. In much the same way the most modern science is connecting together numerous atomic phenomena, in which the above form of unification appears to break down, by means of the invention of quanta of action. Some day, with little doubt, these two forms, which at present appear irreconcilable with one another, will be found to conform to a common law. I wish to argue that, wherever the complexity in laws is found to exist, it indicates a defect in our scientific system which further investigation or a different selection of fundamental quantities will ultimately put right.

We must pass from this somewhat abstract portion to parts which are more important for the practical worker. The question of units and dimensions is discussed in Chapter XIV. Here again we meet with much with which we can heartily agree ; but again the author is rather carried away, in his search for procedure alternative to that usually adopted, into regions bordering on the fanciful. There are many assertions with which we do not agree (for various reasons). The equation, density equals mass ÷ volume, does *not* imply that the density (even of a given substance) is a constant. To define volume as mass ÷ density is to define the easily ascertainable in terms of a quantity (density) which cannot be directly determined. To get over the difficulty by taking the density of a particular substance as an arbitrary unit is to do away with all the advantages of *absolute* units. The present definition of a litre in terms of a mass of water is clearly only a secondary definition, and is on a par with the definition of an electric current in terms of electrolytic deposition. Both these definitions are only adopted for convenience in approximate measurements, and are inconsistent with the International units also adopted. Campbell's dielectric constant K (p. 383, etc.) is the reciprocal of what we have grown accustomed to: it is small when the capacity is great. In the equation

$$[\text{charge}] = [\text{force}]^{\frac{1}{2}} \times [\text{length}] \times [\text{dielectric constant}]^{-\frac{1}{2}}$$

Campbell regards the charge and the dielectric constant as being on a different footing. The dielectric constant is stated to be defined by the above equation while the charge requires other laws. Surely both are equally undefined by the single equation. "Mass, length, and time are not the magnitudes we habitually measure as fundamental magnitudes ; the practical fundamental magnitudes are weight, length, time, and electric resistance." Surely the fundamental magnitudes usually measured all consist of lengths: all the rest is inference. In the footnote on p. 389 occur the two equations $F = \mu\, i\, i^1\, ds\, ds^1/r^2$ and $F = \mu\, mm^1/r^2$. Surely one of the quantities $\mu$ is *inversely* proportional to the other. Much discussion might take place about the justifiability of inserting K and $\mu$ where modern usage introduces them in connection with the dimensions of electromagnetic quantities. Campbell advocates their omission, and twits some writers on priding "themselves on their correctness in including K on every possible occasion." Is it not true, however, that the *only* way of writing an equation in electromagnetics so that it shall be true, whether electrostatic, electromagnetic, or other system of units is employed, is to insert these constants in their appropriate places ? The mention of constants leads me to add that $\mu$ is certainly not always a constant, *i.e.* independent of the field. It is difficult to find a suitable short name in such cases ; what is meant is usually a non-dimensional factor, *i.e.* when its dimensions are ignored; in other cases it is on the same category as the other factors concerned and does not require any distinctive name.

We do not think that, as stated on p. 391, the choice of mass, length, and time as fundamental magnitudes is made because they can be measured more accurately than others; but because in the historical development of physics it was, more or less explicitly, decided to base the definitions of newly-discovered magnitudes (electric charge, current, magnetic pole, etc.) on their mechanical actions.

There is a well-known difficulty in this part of the subject when the fundamental nature of temperature is inquired into. Taking the case of an *ideal* gas as an illustration for which the theoretical equation can be written: $pvM = RT$ where $v$ is the specific volume and M is a characteristic for each gas (in reality the mass of a molecule), the coefficient R is the same for all gases. The product RT has the same dimensions as energy. We may treat R as a no-dimensional constant and T as of the same nature as energy.

We think that this is the course which Campbell considers necessary "if we want to convey by a statement about the dimensions of temperature the most significant assertion and not one merely about an arbitrary and artificial method of measuring it . . . ." We may express this in rather a different but equivalent way by pointing out that in the gas equation R is introduced only to make the equation conform numerically with the Centigrade or other arbitrary scale, and that the product RT might itself be defined as the temperature measured according to the (say) *universal* scale.

One of the chief uses to which dimensions are put is "the argument from dimensions." After stating this well-known argument, he gives a simple illustration and at once falls foul of it. He assumes that the period of a simple pendulum depends only on its length, L, and its acceleration due to gravity, $g$; and finds that the period is a $a\sqrt{L/g}$, where $a$ is presumably the non-dimensional factor. We think that the way he presents the method in this illustration is very imperfect. Why is the mass of the pendulum bob ignored? But Campbell's criticism of the usual reasoning, which he regards as false, seems to depend upon whether the acceleration is uniform or not. If $b$ in the formula $s = \frac{1}{2}bt^2$ can be regarded as an acceleration by a change of the "formal constant" $\frac{1}{2}$, why should we not also change the exponent 2 in $t^2$? "But if we allow that $b$ is an acceleration when it occurs in a law of the form $s = \frac{1}{2}bt^n$, where $n$ is different from 2, the argument fails." Who does allow this? "Again, an acceleration does not mean a constant $b$ occurring in any numerical relation of the form $s = \frac{1}{2}bt^2$, but only one occurring in a numerical law stating, besides a numerical relation, a physical relation" and so on. We are not ashamed to say that we do not see what he is driving at. So far as we can attach significance to it, it appears to mean that we must have defined $g$ before making use of it; but he may mean more than this. We may point out that there is no obvious reason why $g$ should be used at all. In choosing the magnitudes upon which the time-period may possibly depend, its length L, mass $m$, and weight W, all of which have definite values during the vibration, would seem to be the proper choice; not forgetting the amplitude also in a complete application of the method. Putting the last aside for the moment, we obtain the equation $T = a\sqrt{Lm/W}$. But as Newton showed, the time is independent of the mass of the bob, and therefore $W/m$ must be independent of the mass and is denoted by $g$. Of course this last part of the argument may be made first and $g$ employed thenceforward instead of $W/m$. Thus T is determined except for a no-dimensional factor $a$. When the amplitude A is also considered, we have two independent lengths to take into account between which any ratio whatever may exist. But the dimensional equation remains undisturbed if $a$ is taken as *any* function whatever of this *ratio*, for it will then remain of no dimensions as required.

We would have liked to see how temperature is to be dealt with in dimensional equations.

This very fragmentary discussion is intended to give some slight idea of the matters dealt with in this book. It cannot pretend to give a just idea. The work is obviously the production of a very fertile brain, fully cognisant of the facts of physical science. Every page teems with arguments and statements which require to be taken into consideration in order to get a measure of the whole. We wish it had been found possible to shorten the book, especially as it is only the forerunner of several other promised volumes. It must be possible to do this. The great length is largely due to each case being considered on its own. It must be possible to pick out general propositions which can be presented in an orderly fashion so as to present an argument or rather a philosophy which gradually unfolds itself. This is necessary in the interests of economy of thought and mental effort. Until this is done, we cannot think that the book will become popular or even widely read. Many will dip into it, however; and if they do, they will find plenty of material to stimulate their own thinking. Whether they will agree with the author or not is another question. We think that Dr. Campbell should seriously consider this abbreviation and rearrangement before publishing his succeeding volumes. These promise to be of even greater interest to a physicist, and if would be a pity if anyone were deterred from reading them simply owing to the need to economise time.

# REVIEWS

## MATHEMATICS

**Applied Calculus.** By F. F. P. Bisacre, M.A., B.Sc. [Pp. xv + 446, with 5 plates.] (London: Blackie & Son, 1921. Price 10*s*. 6*d*. net.)

This book is intended to provide an introductory course in the calculus for the use of students of natural and applied science whose knowledge of mathematics is slight, and it is an interesting refutation of the idea that an elementary treatment is inconsistent with mathematical rigour. Whether or no the students will appreciate the pains the author has evidently taken in this respect is another matter.

The book is full of "modern instances" which are entertaining even when their introduction does not seem to increase the clarity of the exposition. An interesting and novel feature is the series of biographical notes on and portraits of mathematicians and scientific men whose work is referred to in the text.

The book is written by a mathematician and shows a lamentable lack of appreciation of what is involved in physical measurement. In estimating the total error in calculating the mass of a ring whose density is known only to 1 part in 30, the author finds it necessary to add $\frac{1}{3141}$ "because $\pi$ is not known accurately." Starting with the side of a cube measured to 7 significant figures, he proceeds to calculate, with what he calls "accuracy," the area of a face to 13, and the volume to 19 figures. He reduces these to 7 figures each, not because the remaining figures mean nothing at all, but because "we do not need 19 significant figures for any practical purpose." It seems quite inexcusable that a book intended for students of science should not have been submitted in proof to someone who would have purged it of such examples of one of the most deeply-rooted misconceptions with which the teacher of physics has to contend.

The type of the book is excellent and the diagrams are good. The price is not excessive.

G. A. Sutherland.

**Cours complet de Mathématiques spéciales.** Par J. Haag. Tome II, Géométrie. (Pp. vii + 662.] (Paris: Gauthier-Villars & Cie, 1921. Price 65 fr.)

This book covers familiar ground, the elements of analytical and differential geometry, and presents few novelties in the way of matter or of treatment. Practical utility being the guiding principle, the discussion of conics and quadrics is relatively condensed and is postponed to the latter part of the volume; on the other hand, differential geometry is treated in more detail than is usual in an elementary work. The great drawback to the book is its prolixity, which causes its enormous size and its enormous price. The author has a curious dislike for the ordinary formula, involving $\frac{d^2y}{dx^2}$, for the curvature of a plane curve.

F. P. W.

**Étude géométrique des Transformations birationnelles et des Courbes planes.** Par HENRI MALET. [Pp. viii + 262.] (Paris: Gauthier-Villars & Cie, 1921. Price 32 fr. net.)

THIS book is an attempt to establish a theory of algebraic curves and in particular of their birational transformations without the use of algebra. It is not altogether successful.

The first part deals with the ordinary theory of projectivities between ranges of points on lines; but it is not at all satisfactory. There seem, in fact, to be only two reasonable methods of procedure, either to assume co-ordinates frankly, as is done by Duporcq and Darboux, or else to examine with some degree of logical completeness the axiomatic foundations of the subject (see, for example, the treatment in Whitehead's *Axioms of Projective Geometry*, or in the recent book by Baker: *Principles of Geometry*, vol. i, Foundations). The "fundamental theorem," that a projective correspondence between two lines is completely determined when the correspondents of three distinct points of one line are determined on the other, requires for its proof the introduction of relations of order among the points of a line and the assumption of the Dedekind axiom (or else the assumption of Pappus theorem). M. Malet proves it by vague considerations of continuity and completeness.

The introduction of complex elements too, though in a shadowy way reminiscent of von Staudt (who is not mentioned anywhere in the book), lacks precision and omits propositions which are logically necessary unless algebra is used.

Chapter II contains an interesting treatment of plane cubic curves obtained as "courbes jumelaires" in the quadratic transformation. With this definition the author is able to prove a number of residuation theorems.

In the next chapter we get on to algebraic curves in general and, as was to be expected, on to very treacherous ground. On p. 128 we arrive at this remarkable definition: *Une courbe algébrique est une courbe telle que par $k$ points du plan il en passe une et une seule.* This is, of course, nonsense. As it stands it would mean that only one algebraic curve passes through $k$ points taken in the plane. That is clearly ridiculous, but can the definition be satisfactorily amended? In the first place, $k$ must be of the form $\frac{1}{2}n(n+3)$, where $n$ is a positive integer. The "definition" is evidently meant as a generalisation of "two points determine a line," which cannot be regarded as defining a line, but merely as expressing one of the axioms of incidence assumed between the undefined entities *points* and *lines*. But, even if we interpret it as follows: "Just as two points determine a unique straight line, so five points determine a unique 'conic,' nine points a unique 'cubic,' and so on; all curves so determined are called algebraic," it is clear that this is no definition of algebraic curves. It is impossible to define conics simply as the class of curves of which one and one only passes through five points; it is easy to construct classes of transcendental curves satisfying this condition.

However, the author somehow proceeds from this definition to deduce general properties of algebraic curves, and then gets on to birational transformations. There is a lot of useful and interesting stuff in these last chapters, but it is difficult to be sure that any proposition has really been proved. The diagrams are numerous and carefully drawn, but are often so complicated that they do not greatly help in the elucidation of the text.

It is interesting to notice what M. Malet, himself an engineer, is careful to point out in his footnotes, namely that many of the French geometers, Brianchon, Desargues, Poncelet, Peaucellier, were engineers. There is, however, a regrettable absence of references to German works.

F. P. W.

**Essai philosophique sur les Probabilités.** Par PIERRE-SIMON LAPLACE. Les maîtres de la pensée scientifique. Collection de mémoires et ouvrages. Publiée par les soins de Maurice Solovine. [Two volumes. Pp. xi + 101, 108.] (Paris : Gauthier-Villars & Cie, 1921. Price 7 fr.)

THE excellent series of texts of the classics of science, of which these two volumes form part, has already been welcomed in SCIENCE PROGRESS (January 1922, p. 474). The editorial apparatus consists solely in a brief but useful biographical sketch.

Laplace's *Essai*, which was published separately in 1814, but which is also to be found as the Introduction to his *Théorie analytique des probabilités*, is too well known, at least by repute, to require much comment. Laplace has been blamed for his too sparing use of symbols in this work; it is probably true that his section on the generating function "would not be intelligible to a reader unless he were able to master the mathematical theory delivered in its appropriate symbolic language," and it is perhaps a little difficult to recognise in "une expression très simple, que l'on obtient en intégrant le produit de la différentiale de la quantité dont le résultat déduit d'un grand nombre d'observations s'écarte de la vérité, par une constante moindre que l'unité, dépendante de la nature du problème, et élevée à une puissance dont l'exposant est le rapport du carré de cet écart au nombre des observations" the ordinary error-function. But the *Essai* is very well worth reading, and it is to be hoped that the appearance of this convenient edition will make it more widely read.

F. P. W.

## PHYSICS

**Moderne Magnetik.** Von FELIX AUERBACH. [Pp. viii + 304, with 167 text figures.] (Leipzig: Johann Ambrosius Barth, 1921. Price 48 marks.)

THIS book contains a good account of the experimental facts of magnetism, and a fairly adequate account of the theories, as far as that can be done with a minimum of mathematics. A similar book in English would indeed be welcome. Facts and theories are brought home by means of excellent figures and appropriate tables. There is a good account of Magneto-Optics, a subject usually treated from the standpoint of Physical Optics, and a good summary of the main results concerning the Zeeman effect.

Of the omissions which occur to the writer, the two most important are the absence of any reference to Oxley's work on change of magnetic properties with change of state and, in the chapter on Magnetic Measurements, absence of a description of the Grassot fluxmeter.

The usefulness of the book would be increased by suitable references to the literature of the subject.

J. R.

**Modern Electrical Theory. Supplementary Chapters. Chapter XV, Series Spectra.** By N. R. CAMPBELL, Sc.D. [Pp. vii + 109.] (Cambridge: at the University Press, 1921. Price 10*s.* 6*d.* net.)

THIS is really a monograph on optical and X-ray series spectra. As stated in the preface, the author proposes to supplement and ultimately to replace his well-known book of this title, by issuing from time to time similar monographs dealing with new developments and bringing his original work up to date.

This chapter is marked by the lucidity and thoroughness of the former work. It is not intended for the expert, but for students who, fresh from graduation, wish to get quickly into touch with research. It is explanatory of the main facts of series spectra, and in theory is based on Bohr's conception of the atom with its "steady" electronic orbits. One cannot praise too highly the exceedingly careful manner in which the author has separated and discussed the two features which are common to the laws of all series spectra, bringing home with great point and clarity Ritz's principle of combination before going on to the well-known Balmer-Rydberg-Runge numerical relationships. In no explanation has the writer seen the relation of lines in a spectrum to "terms" so lucidly put. There follow excellent accounts of the quantum hypothesis and its peculiar relation to our classical dynamics, of Bohr's Theory and the generalisation of it due to Sommerfield, of the quantum treatment of the Zeeman and Stark effects, and of the bearing of relativity theory on the explanation of the fine structure of high-frequency lines. Sections on the intensity of spectral lines and on band spectra conclude a volume which no student of physics should fail to read if he wishes to see a very large body of recent theoretical and practical research dealt with in a compass remarkably small considering the wealth of material available for selection.

J. R.

**L'atome—Sa structure, sa forme. Les Edifices physicochimiques, Tome I.** Par DR. ACHALME. [Pp. 244.] (Paris: Payot et Cie, 1921. Price 15 frs.)

THIS work is the first of a series of eight volumes, in which it is sought to give a rational interpretation of all chemical and biological phenomena. In the present volume the author has exercised much ingenuity and but little circumspection in the elaboration of a theory of the structure of the atom. On the assumption that the charge on the electron is twice as great as that on the positive hydrogen nucleus, he constructs diagrams illustrating the atomic structure of the principal elements.

The book appears to have been written some years ago, for no mention is made of the recent theoretical and experimental work on the subject. Thus it is stated on page 76 that chlorine consists of isotopes of atomic weights 35 and 39, whereas Aston has shown these to be 35 and 37 respectively.

The work is almost entirely speculative.

W. E. G.

## CHEMISTRY

**A Comprehensive Treatise on Inorganic and Theoretical Chemistry.** By J. W. MELLOR, D.Sc. [Vol. I (H; O), pp. xvi + 1065, with 274 diagrams; Vol. II (F, Cl, Br, I, Li, Na, K, Rb, Cs), pp. viii + 894, with 93 diagrams.] (London: Longmans, Green & Co., 1922. Price £3 3*s*. net each volume.)

IN the early days of chemistry it was the custom for textbooks and treatises to be written by one or two chemists who were able to assimilate the whole, or one of the chief divisions, of chemistry, and then to present it in readable form for the benefit of others; we have only to think of Thompson's *New System*, of Roscoe and Schorlemmer's *Inorganic Chemistry*, or of Meyer and Jacobson's *Lehrbuch der organischen Chemie*, to realise this.

At the present day, however, the tendencies have been in two directions: either for individuals to write monographs dealing with certain special subjects with which they are familiar, or else for a number of writers to collaborate under a general editor. The first method has the advantage that the expert can write up his pet subject in a manner not otherwise possible, but there is the disadvantage that the multiplicity of actual or threatened monographs is so great that no chemist has time to do much more than to glance through a few of them.

The second method has the advantage of keeping subjects within strict limits, but there is the inevitable disadvantage that a book written by several hands cannot secure quite the same uniformity of treatment and sense of continuity that is possible where the entire work has been written by one man.

The only trouble is to find the man. Dr. Mellor has solved this part of the problem satisfactorily, and has undertaken to settle the other difficulties by himself compiling a whole treatise on general chemistry from start to finish.

It is difficult to know whether one feels the more amazed at Dr. Mellor's audacity in setting himself the task of composing a general treatise on chemistry, or at the extraordinary patience and perseverance which have enabled him to complete already two of the six or seven volumes which are promised.

He aims at describing all the compounds known in Inorganic Chemistry, and, where possible, these are discussed in the light of the so-called Physical Chemistry, which Dr. Mellor quite rightly regards as a branch of general chemistry, and not as a science in itself, as some of its devotees would have us believe.

The work is intended to cover a larger range of facts described in greater detail than can be found in any work hitherto published, together with copious lists of references which will be of very great value to all chemists, both academic and industrial.

The first volume is largely of an introductory character, dealing with the early history of chemical philosophy and including a general discussion of various physico-chemical conceptions such as thermodynamics, the phase rule, electro-chemistry, and so on; in addition, hydrogen and oxygen and their compounds are described in detail.

Vol. II covers the halogens and the alkali metals and ammonia, and it is intended that Vol. III shall deal with copper, silver, gold, the alkaline earths, radio-activity, and the structure of matter, whilst later volumes will be set aside for the remaining elements arranged for the most part according to the periodic law, though Dr. Mellor disavows any blind faith in the law as a perfect scheme for classifying chemistry.

Occasionally one has a faint suspicion that Dr. Mellor's pen has run away by itself, as, for instance, in the little moral lecture on p. 358, Vol. I, on Not Placing Too Much Trust In Words; it is all very true, but the only question is whether a treatise on Chemistry is quite the right place for such little homilies. Again, the quotations at the head of each chapter, although excellent, are perhaps a little out of place in a cold, calculating textbook.

Yet, after all, they are but the expression of the individuality of the author, and a chemistry book should be something more than a mere soulless card-index of disconnected facts, and if the quotations do not help greatly to the understanding of the contents of the chapters, they serve to remind one of the fact that the book is permeated with the personality of the author.

If Dr. Mellor can keep the remaining volumes promised up to the standard which he has set in the present ones, he will have achieved something like a record, and created a work of which not only author and publishers may be proud, but which we shall feel to be a real credit to British Chemistry.

F. A. M.

**Laboratory Exercises in Applied Chemistry for Students in Technical Schools and Universities.** By Dr. Wilhelm Moldenhauer. Translated by Lawrence Bradshaw, D.Sc., Ph.D. [Pp. xii + 226, with 36 figures.] (London: Constable & Co., 1922. Price 12*s*. 6*d*. net.)

This book is essentially a "practical" work, and is intended chiefly for students at technical colleges and the like who will be going into the chemical industry later.

Not only is care taken to explain the nature of the reactions involved in the various analyses, but emphasis is laid upon their technical application in order that the student may readily understand why certain precautions are essential in some cases and not in others, and the manner in which the processes in question may depend upon the speed or accuracy of the analyses. Subjects dealt with include such matters as coal, water, Chile saltpetre, basic slag, iron and its ores, soap, oleum, and so on.

It should be of considerable value to those who have to teach analytical methods to technical students.

F. A. M.

**The Chemistry of Colloids, and some Technical Applications.** By W. W. Taylor, M.A., D.Sc., Lecturer in Chemical Physiology at the University of Edinburgh. [Second Edition. Pp. viii + 352.] (London: E. Arnold & Co., 1921. Price 10*s*. 6*d*. net.)

The first edition of this book was reviewed in this Journal (vol. x, p. 167) in 1916, and the present volume does not differ very appreciably from the earlier edition; though only some extra 24 pages have been added, this does not mean that a good deal of revision has not been undertaken. This has, however, been done only where either the new matter was a more convincing illustration of an already established theory or the new experimental results had led to changes in the previously accepted theory.

It is questionable whether too much is not attempted in endeavouring to give the more important applications of colloid chemistry in 28 pages, but at all events these will serve as an introduction to more specialised treatises.

In any case, the fact that a second edition is called for indicates that we are already far from the days when a certain Professor of Chemistry used to advise his students, "Don't marry too young and don't work with anything that isn't crystalline!"

Dr. Taylor's book in its revised form will no doubt secure many fresh readers, and can be recommended to all seeking an introductory work on colloid chemistry.

F. A. M.

## GEOLOGY

**Textbook of Geology.** By L. V. Pirsson and C. Schuchert. Part I, Physical Geology, by L. V. Pirsson. [Pp. vii + 470, with 2 plates and 417 text figures.] (New York: John Wiley & Sons, 1920. Price 17*s*. 6*d*. net.)

The favourable reception which was accorded this work, first issued in 1915, has resulted in the necessity for the preparation of this second edition. During the five years which had elapsed since its appearance, the book had established itself as one of the most clearly expressed and impartial discussions of the subject, and its value to the general student had been universally recognised. It is, therefore, all the more regrettable that the appearance of the second edition synchronised with the death of the author; Prof. Pirsson died at the end of 1919, practically his last work being the revision of the text of this treatise.

On comparing this edition with the previous one, the only apparent difference is the addition of thirty pages, various portions of the text being amplified by the addition of further explanatory paragraphs. Otherwise the arrangement and subject-matter remain as in the first edition. The lucidity of the descriptions, the excellence of the diagrams, and the fact that the book can be regarded as thoroughly up to date, combine to render the book one which can be recommended not only to students, but also to the general reader interested in geology.

A. S.

**The Elements of Engineering Geology.** By H. Ries, Ph.D., and T. L. Watson, Ph.D. [Pp. v + 365, with 252 figures.] (New York: John Wiley & Sons. Price 22*s.* net.)

In recent years the acquirement of a knowledge of geology has become an essential part of the training of an engineer, for, in practically all branches of engineering, problems necessitating such a knowledge are encountered. Not only are the general principles of the subject of great value in such work as roadmaking, water-supply, and so forth, but there has also sprung up a special branch of geology dealing with those peculiar properties which are responsible for the utilisation of particular rocks for specific purposes. Methods have been devised for the grading of materials, for the determination of the resistance of the materials to abrasion and to impact, for the determination of permeability to water, and for the investigation of other properties ignored to some extent in general geology.

Some years ago the authors of the book under review issued a comprehensive work on Engineering Geology; the present book has been written in order to meet a demand for a more elementary treatment of the same subject. The following chapter headings will give some idea of the scope of the work: The Important Rock-making Minerals; Rocks and their Relations to Engineering Work; Structural Features and Metamorphism; Rock-weathering and Soils; Development, Work, and Control of Rivers; Underground Water; Landslides, Land Subsidence, and their Effects; Relation of Wave Action and Shore Currents to Coasts and Harbours; Origin and Relation of Lakes and Swamps to Engineering Work; Origin, Structure, and Economic Importance of Glacial Deposits; Road Foundations and Road Materials; Ore Deposits; Geologic Column.

In each case the subjects are considered from an engineering point of view, emphasis being laid on those aspects of the phenomena and properties of the materials which are of engineering importance. The descriptions throughout are clearly expressed and well illustrated by an excellent series of photographs, diagrams, and maps, while at the end of each chapter references to the more important papers on the subject are given. If the book has any fault, it is that of brevity; the omission of certain physical data and of descriptions of the methods of testing is to be regretted, but, in view of the professedly restricted nature of the book, not unexpected.

A. S.

## BOTANY

**Fungi. Ascomycetes, Ustilaginales, Uredinales.** By Dame Helen Gwynne-Vaughan (formerly H. C. I. Fraser), D.B.E., LL.D., D.Sc., F.L.S. Professor of Botany in the University of London and Head of the Department of Botany, Birkbeck College. [Pp. xi + 233, with 196 illustrations.] (Cambridge: At the University Press, 1922. Price 35*s.* net.)

This is the third volume of the Cambridge Botanical Handbooks issued so far. The author describes in the special section of this work the morphology, cytology, and relationships of the Ascomycetes, Uredinales, and Ustilaginales. She has previously contributed a series of memoirs dealing with the difficult problem of the sexuality of the former two groups, and here she sums up the evidence against the very plausible view of Claussen that in the Ascomycetes there is but one fusion—that in the ascus, and that previous to this only a nuclear association in pairs occurs. Preceding this critical survey is an historical summary of the earlier investigations into the origin of the ascocarp from the times of Bulliard onwards to the De Bary–Brefeld controversies.

The essential features of each family are described and bibliographies given supplementary to those given in De Bary's *Morphology of the Fungi Mycetozoa and Bacteria.* As regards the origin of the Fungi and their interrelationships, the author holds that conclusions " must await a detailed knowledge of the development of the ascocarp and of the morphology of the sexual apparatus in a much larger number of species." A new group, the Plectomycetes, is formed to include all Ascomycetes, not definitely Discomycetous or Pyrenomycetous, *i.e.* the Erysiphales, the Exoascales, and the Plectascales.

The introduction concerns itself with the general morphology of the Fungi and with their physiology, especially where it throws light on their saprophytism or parasitism. Such subjects as specialisation, bridging species, reaction to stimuli, the recent work of Blackman and Brown on the method of entry of certain parasitic fungi into their hosts are all summarised. Many of the illustrations are original, and the others are reproduced from recent memoirs. The book meets a very real want and forms a welcome addition to this excellent series. E. M. C.

**Cane Sugar.** A Textbook on the Agriculture of the Sugar Cane, the Manufacture of Cane Sugar, and the Analysis of Sugar-House Products. By Noël Deerr. Second (revised and enlarged) Edition. With illustrations and coloured plates. [Pp. viii + 644.] (London: Norman Rodger, 1921. Price 42*s*. net.)

This is an essentially practical book written by one who has first-hand knowledge of the subject gained by experience both on the plantation and in the refinery. As implied in the sub-title, the agriculture of the sugar-cane is also dealt with, and, as a matter of fact, receives much fuller consideration than is generally accorded this subject in similar books ; the first ten out of a total of twenty-eight chapters are, in fact, concerned with the description of the sugar-cane and its varieties, illustrated by a number of excellent colour-plates, and the manuring, irrigation, husbandry, and diseases of the cane. Then follow chapters devoted to the various processes employed in the production of the sugar, such as extraction by crushing, and also the defunct process of diffusion borrowed from the beet-sugar industry, defecation, carbonation, sulphitation, filtration, sugar boiling, etc., dealt with both from the practical and the theoretical points of view, including mathematical calculations dealing with the distribution of heating surface for maximum evaporation effect, the methods of utilisation of steam, and an algebraical analysis of the process of milling. Factory control, methods of analysis, molasses, utilisation of bagasse as fuel, and fermentation and distillation all receive consideration, and the volume is brought to a conclusion with a useful appendix of twenty-odd pages containing a bibliography, an index of patents, and, last but not least, an historical conspectus. This latter will probably appeal particularly to the general reader who wishes to obtain a rapid survey of the history and development of the industry in addition to consulting the book for the details of any particular process. Those particularly interested in the natural history of the cane and its varieties, and in the experiments which have been carried out on its propagation by sexual and other means, will find an interesting and fairly exhaustive historical account in Chapter IV. The book is very well got up and somewhat handsomely bound, and should form a valuable book for reference and general information on the sugar-cane industry.

## ZOOLOGY

**Ocean Research and the Great Fisheries.** By G. C. L. Howell. [Pp. 220, with 3 charts, 20 plates, and 26 figures in the text.] (Oxford: at the Clarendon Press, 1921. Price 18*s*. net.)

Early in 1917 the reconstruction of the temporarily disorganised sea-fishing industry was being anticipated. There was much activity at the

Ministry of Agriculture and Fisheries, where plans of further research and development were being thought out. At the same time those concerned with the actual industry had formed committees and were planning out the reconversion of the fishing fleets, believing that there would be considerable confusion as soon as peace was assured. So schemes for the reorganisation of the statutory fishery authorities; for the training of fisher lads; for better distribution of the fish caught; for scientific research and for codification and simplification of the unnecessarily complex fishery legislation were drafted and printed. More interesting still, a plan for the creation, by Royal Charter, of a British Fisheries Society was made; a petition was drawn up and steps were taken to raise the necessary money. The enthusiasm with which the industry plunged into reconstruction may be recalled when one notes that they confidently expected to be represented, in some way, at the Peace Congress, and also that it was actually suggested that the Island of Heligoland should be internationalised and made the centre of a European fishery research organisation. All these plans and thought-out proposals deserved a better fate.

For they were all unsuccessful. Little by little the activities of the Ministry, in respect to fisheries, have sunk to rather below the pre-war standard, both with regard to development and research. The money for the endowment of the British Fisheries Society was not forthcoming. Education and research became rather more poorly off than they were in 1913. Nothing was said about fisheries at the Peace Conference, and Heligoland is become a trippers' resort. By the end of 1919 wholly unexpected difficulties crowded about the fishing industries, and the entire efforts of the owners were soon concentrated on keeping their business going. Even now fish are dear in the shops and, every week or so, quite unsaleable at the docks. To explain this paradox would involve one in debatable economic questions which would certainly disturb the scientific calm of this Journal! But this comes out of reflection on the experiences of 1917–1919: bitter disillusionment with regard to our methods of government and industry.

The author of the book now being reviewed must surely be the most "fed-up" of all those who took part in the fishery reconstruction movement! He arranged the long series of meetings and conferences that were held at Fishmongers' Hall between the representatives of the English and Scottish industries on the one hand, and the scientists on the other. He was Organising Secretary for the British Trawlers' Federation. It is quite proper to say that the owners of fishing vessels paid him £1,000 a year—because that shows their sincerity and earnestness in the attempt to build up a reconstructed fishing industry. He was the provisional Secretary of the stillborn British Fisheries Society. He and his committees put an enormous amount of work into their efforts to replace the present patchwork of fishery authorities by something rational and obviously *made*. These committees were composed of men who had big interests and whose time was valuable (Sir Edward Busk, for instance, was their chairman), and their efforts deserved a better fate. It is believed that the Fishery Departments and the Government were dimly aware of their existence and reports, but the belief lacks conviction.

This book is the outcome of Captain Howell's propagandist work. It is a plain and, on the whole, accurate presentation of the salient things in the life-history of the British sea-fisheries; written with a clearly indicated attitude and purpose—to bring together the business and scientific men. That is its message, suggested or even insisted upon on every other page. It is up-to-date, very plainly written, and very beautifully printed and illustrated. Primarily it is intended for the men in the industry, but it has very obvious interest for naturalists and professional zoologists. Just now it is difficult to say what is going to become of the British deep-sea fishing industry: that will continue, of course, but it may well be that, as things are, it will never again become what it was in August 1914: a ready and "sure shield and defence." To reconstitute it as such means that the organisation that, with rare courage and faith, looked out from Fishmongers' Hall in the years 1917–1919 on a possible new world, will have to be set up again, and when that happens our author will receive his reward. J. J.

**Lake Maxinkuckee, a Physical and Biological Survey.** By B. W. Evermann, A.M., Ph.D., and H. W. Clark, A.B., A.M. [Pp. 1150, with 36 plates, of which 32 are coloured, and 24 figures.] (The Department of Conservation, State of Indiana, 1920. Price $5.25.)

This is probably the most extensive survey of a fresh-water lake that has been made in North America, and will doubtless serve as a standard reference-book for a long time to come. The work was carried on under the direction of Dr. Barton W. Evermann, well known as an ichthyologist, and occupied a number of years. The fish in particular are very fully treated, and this part of the report is illustrated by numerous plates. The physical portion deals with the physical surroundings, the hydrography, temperature variations in water and air, and so on. The work is divided into two volumes, of which the first contains the two sections mentioned above, the mammals, the birds, the reptiles, and the amphibians. The second volume treats of the insects, molluscs, crustaceans, leeches, Protozoa and Cœlenterata, worms, sponges, land flora and aquatic flora.

As the lake itself is typical of a number of the lakes of North America and so the survey will be of considerable use in similar localities, but not only that: it will present to other scientists a very full picture of the conditions, the flora and fauna of one of these areas that are so characteristic of this part of the world.

The authors are to be congratulated on bringing to such a successful conclusion a piece of work involving the expenditure of a great deal of time and labour. The Department also deserves congratulations, not only on the splendid manner in which the books are produced, but also for their foresight in instituting the survey and having it carried out. It is only by making knowledge of this sort available that the conservation of the resources of a country can be satisfactorily carried out.

It is a book that should find a place on the bookshelf of all naturalists and zoologists. C. H. O'D.

**Organic Dependence and Disease: Their Origin and Significance.** By John M. Clark, D.Sc., LL.D. [Pp. 113, with 105 figures.] (Yale University Press; Oxford University Press, 1921.)

The author has dealt with this subject from a palæontological point of view: that is to say, he has studied the evidence of the palæontological records of animals living together in various ways from the earliest times. It is of course well known that the fossils of one animal bear clear evidence of other forms intimately related to it, but it is probably not generally realised how extensive this evidence is and how many different species had other species living with or on them. The various types are described clearly and illustrated by very good figures, and the author has laid other workers under a debt for the way in which he has done this.

As he himself points out, he does not use the term Disease in the way in which it would be employed by a physiologist or pathologist, for obviously we can have no exact knowledge of the interference with the normal functions of one animal that were brought about by another. In fact, he appears to regard the adaptations, degenerative or otherwise, undergone by the "parasite" as evidence of disease. In our opinion the discussion is not simplified by the use of words like "methuselan stability," "vibratile vitalism," "recreants" for such forms as barnacles and so on. Apart from this, however, the book is very interesting to read and quite suggestive. It also contains a great deal of useful information. The illustrations, some of the stereoscopic, deserve special commendation.

C. H. O'D.

## ANTHROPOLOGY

**The New Stone Age in Northern Europe.** By John M. Tyler. [Pp. xviii + 310, with 23 illustrations.] (London: G. Bell & Sons, 1921. Price 15*s.* net.)

Professor Tyler has produced in this volume a popular and interestingly written account of the European Neolithic Period, with special reference to the relics of that period found in Scandinavia. There are twelve chapters in the book, of which the first is introductory and deals with the origin and earlier history of man. Other chapters deal with such subjects as pit-dwellings, lake-dwellings, megaliths, Neolithic chronology, migrations, and Neolithic religion. The work is comprehensive and no important aspect of European Neolithic life is ignored. There is a good deal of unfounded speculation, in the introduction, regarding human origins, but much of the book is good. The descriptions of the Magelmose settlement and of the geographical changes in the Baltic region, for instance, are good, and make most attractive reading. The most serious blemish in the book is the author's treatment of chronology. He gets tied up in the glacial, interglacial, and post-glacial phases, and puts forward mutually inconsistent theories in different parts of the book, apparently without fully realising the discrepancies. The reader who really wishes to master this subject will not get anything out of the author's incoherent descriptions. In Chapter I he gives a brief but consistent account of the so-called "French" chronology, placing the Mousterian mainly in the Würmian phase and the Magdalenian in the Bühl phase. In Chapter II he appears to adopt the "German" (*i.e.* Penck's) chronology, which places all the archæological ages further back. And then again in Chapter VIII, which is specially devoted to chronology, he brings the end of the Magdalenian right down to the Gschnitz phase, which is certainly wrong and is inconsistent with what he has said in earlier chapters. It is unfortunate that the author was not more careful in the treatment of this part of his subject, as it is essential to a proper study of late prehistoric times; and his shortcomings in this respect largely spoil what should have been a good and informing book.

A. G. T.

## MISCELLANEOUS

**Elementary Chemical Microscopy.** By E. M. Chamot, B.S., Ph.D. Second edition, partly rewritten and enlarged. [Pp. xv + 477, with 160 diagrams.] (New York: John Wiley & Sons; London: Chapman & Hall. Price 25*s.* net.)

Six years have elapsed since the publication of the first edition of this book and during that time considerable advance has been made in the use of the microscope as a necessary adjunct of the chemical laboratory.

The book is intended to serve as an introduction to the microscope and its accessories as tools for the chemist to work with, and even though practical applications are referred to, the author states that he has made no effort and has no desire to have the book take the form of a manual of industrial microscopy.

The early part of the work is devoted to microscope objectives and oculars; the selection of these for particular purposes is dealt with and sufficient of the elementary theory of microscopic optics is indicated to enable a worker to get the best out of his instrument. The only point to be regretted in this section is, that apparently the author regards penetration and flatness of field as something to be greatly desired in an objective. It is, however, now universally recognised that these qualities are rather of a negative character, and that they can only be secured by sacrificing other qualities that are of greater importance.

Different methods of illumination and appliances for obtaining these results are described, and the illumination of objects by transmitted light, as well as that ordinarily known as dark-field illumination, is well dealt with. The method of using ultra-violet light, both for photographic purposes and for observation of the fluorescent image produced thereby, is referred to, but it cannot be said that the description is sufficiently accurate, or complete enough to enable anyone to attempt such work. Very few microscopes are described, and then only so that the type may be appreciated. This is a point that might well be followed in other books of this character, as it is quite easy to refer to makers' catalogues to know what microscopes are being produced ; one hardly needs a large portion of a book to be devoted to what are, after all, but abstracts from these catalogues.

Various types of ultra-microscopes are described in contradistinction to the ordinary dark-ground illuminator. It is rather to be regretted that the point of difference between resolution in the microscope and the visibility that can be secured by any method of dark-ground illumination is not more fully dealt with both in theory and practice.

The chapter on useful microscope accessories and laboratory equipment is of considerable interest, and should prove of service to those other than chemists who have occasion to use the microscope.

The chapter on Micrometry is equally useful. There follow sections on Quantitative Analysis by Means of the Microscope, the Determining of Melting and Subliming Points, the Determination of Refractive Index by Means of the Microscope, the Examination of Crystals under the Microscope, and methods for handling certain classes of material, and all of these are of great interest.

Chapters XIII, XIV, and XV refer particularly to the methods of micro-chemical qualitative analysis, and reference to the book itself must be made for this portion to be appreciated.

In general the book may be regarded as a praiseworthy effort to deal with the subject of its title, and may be commended to those engaged in micro-chemical work.

J. E. B.

**The Microscope.** A Simple Handbook by Conrad Beck. [Pp. 144, with 131 figures.] (London : R. & J. Beck, 1921. Price 2*s*. 6*d*. net.)

This book is intended as a guide to the use of the microscope. The correct use of the instrument follows directly from a knowledge of the functions of the different parts ; it has therefore been found best to develop the method of manipulation in the course of the descriptions of its component parts. Such particulars as are given of the optical principles and construction are of the simplest character, and their comprehension requires no optical knowledge. Certain theoretical matters are referred to in this book, but are not explained. Some of the descriptions may appear to be extremely elementary to experienced microscopists, but even they may find useful matter which is not available in the ordinary textbooks.

The earlier part of the book describes the various accessories that are available and the method of their use ; the mechanical construction of the stand being left to the last, a course of procedure that has much to recommend it.

The importance of illuminating apparatus is fully recognised, and methods of use are described in such a way as to be intelligible to the novice.

An early section is also devoted to the method of holding microscopic objects and of dealing with them so that they may be satisfactorily examined —a point that is often largely overlooked in textbooks of this kind.

An adequate description of objectives and oculars follows, together with the method of adjusting them to obtain the best results under any ordinary conditions of use.

Microscopes of various types are described, not only the monocular, but also the binocular type, together with those that are intended for the examination of metallurgical and other specimens.

The book closes with a short chapter on the observation of microscopic objects, a part that is evidently intended for the beginner, but it is nevertheless of interest and indicates the direction in which those undertaking microscopic work may look for objects of interest.

All the apparatus described is made by Messrs. R. & J. Beck Limited, so that the book does not form a complete guide for those who wish to make a selection from various makers' productions. It is, therefore, admittedly in the nature of an advertisement, but the whole matter is so good and the description of the use of various parts is so adequate that it really hardly loses anything from what otherwise might be regarded as a serious shortcoming. It may be recommended to the beginner who wishes to obtain some knowledge of the elementary optics and practical use of the microscope.

J. E. B.

**Through Angola. A Coming Colony.** By Colonel J. C. B. Statham, C.M.G., C.B.E. [Pp. xvi + 388.] (Edinburgh and London: William Blackwood & Sons. Price 28*s*. net.)

Colonel Statham's book is a valuable addition to the increasing number of authoritative works on portions of the African Continent. The book is divided into two parts; the first being mainly descriptive of the author's journeys in the colony together with his quest for the giant sable; while the second is a short account of the colony's history, its present economic state, and chapters on the fauna, flora, tribes and their customs, and the future prospects of Angola.

There is much information throughout the book for the prospective settler, the sportsman, the naturalist, and the traveller.

The first thing that strikes the reader, if he is a sportsman or naturalist, after perusal of Part I, is the necessity of protection for the beautiful fauna and more particularly the giant sable, whose sole habitat occupies a comparatively small area of the colony. There can be little doubt that this beautiful creature is doomed unless the Portuguese make more stringent game regulations and, what is equally important, see that they are carried out. No sportsman could possibly want more than three well-chosen specimens of each of the rarer species for his collection, and if, as the author suggests, the game is properly protected as it is in the British Protectorates and Colonies, and the cost of the game licence increased, the country would attract sportsmen who might be impressed by its fertility and wish to remain and take up land or oil and mineral concessions. In any case, the hide hunter should without delay be prevented from pursuing his nefarious occupation.

As regards the author's remarks on p. 213 concerning the negro's neglect of his master during sickness, the reviewer's experience, after many years spent amongst various tribes, is that servants of whatever race, if they know their master well, will never neglect him, but will, on the contrary, not only stick to him through thick and thin, but will not infrequently give their lives for him.

A great deal of Part II has been culled from the works of Portuguese, Italian, Dutch, and French writers, to whom the author gives due acknowledgment. The mass of data in this part of the book might have been better arranged. The meteorological tables, for example on pp. 316 and

317, might have been relegated more conveniently to an appendix at the end of the book, while further appendices might have contained the lists of the fauna, avifauna, and flora with their scientific and local names.

There are several printer's errors which should have been rectified when the proofs were read, and not a few of the scientific names are incorrect. For example, on p. 273 there are no less than three errors. The Cape Hunting Dog is *lycaon pictus*; the Wild Cat, *F. ocreata*; and the Lemur, *galago*. On p. 271 the Leopard should be *felis pardus*; and on p. 262 the Greater Kudu should be *strepsiceros kudu*.

The idea of faintly impressing the spoor of the animal over the text is an innovation, and should prove very helpful to big-game hunters who are not familiar with the particular species.

The book is profusely illustrated with the author's own photographs, and these are all excellent and greatly enhance the value of this admirable book. We will look forward to Colonel Statham's next book and trust that he will have better luck with his telephotographs, only three of which are included in this volume. R. E. Drake-Brockman.

## BOOKS RECEIVED

*(Publishers are requested to notify prices)*

The Origin and Development of the Quantum Theory. By Max Planck. Translated by H. T. Clarke and L. Silberstein. Being the Nobel Prize Address delivered before the Royal Swedish Academy of Sciences at Stockholm, June 2, 1920. Oxford: at the Clarendon Press, 1922. (Pp. 23.)

James Stirling: A Sketch of his Life and Works along with his Scientific Correspondence. By Charles Tweedie, M.A., B.Sc., F.R.S.E., Lecturer in Pure Mathematics, Edinburgh University. Oxford: at the Clarendon Press, 1922 (Pp. x + 213.) Price 16*s*. net.

First Course in the Theory of Equations. By Leonard Eugène Dickson, Ph.L., Correspondant de l'Institut de France, Professor of Mathematics in the University of Chicago. New York: John Wiley & Sons; London: Chapman & Hall, 1922. (Pp. vi + 168.) Price 8*s*. 6*d*. net.

Relativity for all. By Herbert Dingle, B.S., Lecturer in Astrophysics at the Imperial College of Science and Technology. London: Methuen & Co., 36 Essex Street, W.C. (Pp. vii + 72.)

Physique elémentaire et théories modernes. Par J. Villey. Première Partie: Molecules et atomes. États d'équilibre et mouvements de la matière. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1921. (Pp. x + 197.) Price 15 frs.

La théorie de la relativité et ses applications à l'astronomie. Par M. Émile Picard. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. Pp. 27.)

Éther ou relativité. Par Maurice Gandillot. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. 84.)

Space-Time-Matter. By Hermann Weyl. Translated from the German by Henry L. Brose. London: Methuen & Co., 36 Essex Street, W.C. (Pp. xi + 330, with fifteen diagrams.) Price 18*s*. net.

Le principe de relativité et la théorie de la gravitation. Par M. Jean Becquerel, Professeur au Museum National d'Histoire Naturelle. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. ix + 342.) Price 25 frs.

Readable School Physics. By J. A. Cochrane, B.Sc., Higher Grade School, Tranent, East Lothian. London: G. Bell & Sons, 1922. (Pp. xi + 131, with 8 plates.) Price 2*s*. 4*d*. net.

Essai d'optique sur la gradation de la lumière. Par Pierre Bouguer.

Paris: Gauthiers-Villars et Cie, 55 Quai des Grands-Augustins, 1921. (Pp. xx + 129.)

Physico-chemical Problems relating to the Soil: A General Discussion held by the Faraday Society (10 Essex Street, Strand). Reprinted from the *Transactions of the Faraday Society*, vol. xvii, part 2, February 1922. (Pp. 217–368.) Price 10*s*. 6*d*. net.

Electricity. By Sydney G. Starling, A.R.C.Sc., B.Sc., F.Inst.P., Head of the Department of Physics in the West Ham Municipal College. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. viii + 245, with 127 illustrations.) Price 10*s*. 6*d*. net.

A Treatise on the Analysis of Spectra: Based on an Essay to which the Adams Prize was awarded in 1921. By W. M. Hicks, F.R.S., Emeritus Professor of Physics in the University of Sheffield. Cambridge: at the University Press, 1922. (Pp. 326.) Price 35*s*. net.

A Dictionary of Applied Physics. Edited by Sir Richard Glazebrook, K.C.B., B.Sc., F.R.S. In Five Volumes. Vol I, Mechanics and Engineering—Heat. London: Macmillan & Co., St. Martin's Street, 1922. (Pp. ix + 1067.) Price £3 3*s*.

A Comprehensive Treatise on Inorganic and Theoretical Chemistry. By J. W. Mellor, D.Sc. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Vol. I, H,O, xvi + 1065, with 274 diagrams. Vol. II, F, Cl, Br, I; Li, Na, K, Rb, Cs, pp. viii + 894, with 92 diagrams.) Price £3 3*s*. each.

Distillation Principles and Processes. By Sydney Young, M.A., B.Sc., F.R.S., with the collaboration of Lieut.-Col. E. Briggs, D.S.O., B.Sc., T. Howard Butler, Ph.D., M.Sc., F.I.C., and others. London: Macmillan & Co., St. Martin's Street, 1922. (Pp. xiii + 50, with 210 illustrations.) Price 40*s*. net.

The Elements of Fractional Distillation. By Clark Shove Robinson. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. ix + 205, with 41 figures.) Price 12*s*. 6*d*. net.

Metallurgy of Zinc and Cadmium. By H. O. Hofman, E.M., Met.E., Ph.D. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. xii + 341.) Price 20*s*. net.

An Introduction to the Principles of Physical Chemistry from the Standpoint of Modern Atomistics and Thermodynamics. A Course of Instruction for Students intending to enter Physics or Chemistry as a Profession. By Edward W. Washburn, Second Edition, revised, enlarged, and reset. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. xxvii + 516.)

The Chemistry of Combustion. By J. Newton Friend, D.Sc., Ph.D., F.I.C., Carnegie Gold Medallist. London: Gurney & Jackson, 33 Paternoster Row, E.C., 1922. (Pp. vii + 110, with 24 figures.) Price 4*s*. net.

The Homogeneous Electrothermic Effect, including the Thomson Effect as a Special Case. By Carl Benedicks. London: Chapman & Hall, 11 Henrietta Street, W.C.2. (Pp. 117.) Price 15*s*. net.

A Concise History of Chemistry. By T. P. Hilditch, D.Sc., F.I.C. Second Edition, revised. London: Methuen & Co., 36 Essex Street, W.C. (Pp. xi + 276, with 16 diagrams.) Price 6*s*. net.

Colloid Chemistry of the Proteins. By Prof. Dr. Wolfgang Pauli, Director of the Laboratory for Physico-chemical Biology, University of Vienna. Translated by P. C. L. Thorne, M.A., A.I.C., and Sir John Case, Technical Institute, London. Part I. London: J. &. A. Churchill, 7 Great Marlborough Street, 1922. (Pp. xi + 140, with 27 diagrams and numerous tables.) Price 8*s*. 6*d*. net.

Inorganic Chemistry. By T. Martin Lowry, C.B.E., M.A., D.Sc., F.R.S., Professor of Physical Chemistry in the University of Cambridge. London: Macmillan & Co., St. Martin's Street, 1922. (Pp. x + 943, with 285 figures.) Price 28*s*. net.

A Dictionary of Applied Chemistry. By Sir Edward Thorpe, C.B., LL.D., F.R.S. Assisted by Eminent Contributors. Vol. III, Explosives. Revised and enlarged edition. London: Longmans, Green & Co., 29 Paternoster Row. (Pp. viii + 735, with illustrations.) Price £3.

Chimie et Fabrication des Explosifs. Par Paul Verola, Ingénieur en chef des Poudres. Paris: Librairie Armand Colin, 103 Boulevard Saint-Michel, 1922. (Pp. vi + 202.) Price 5 frs.

Power Alcohol: its Production and Utilisation. By G. W. Monier-Williams, O.B.E., M.C., M.A., Ph.D., Fellow and Member of Council of the Institute of Chemistry. London: Henry Frowde and Hodder & Stoughton, 1 & 2 Bedford Street, Strand, W.C.2. (Pp. xii + 323, with 48 illustrations.) Price 21*s*. net.

Chemical Technology and Analysis of Oils, Fats, and Waxes. By Dr. J. Lewkowitsch, M.A., F.I.C. Sixth Edition, entirely revised by George H. Warburton. In Three Volumes. Vol. II. London: Macmillan & Co., St. Martin's Street, 1922. (Pp. xii + 959, with illustrations and tables.) Price 42*s*. net.

Some Physico-Chemical Themes. By Alfred W. Stewart, D.Sc., Professor of Chemistry in the Queen's University of Belfast. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. xii + 419, with 5 plates and 37 diagrams.) Price 21*s*. net.

Fluidity and Plasticity. By Eugene C. Bingham, Ph.D., Professor of Chemistry at Lafayette College, Easton, Pennsylvania. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie St., E.C.4, 1922. (Pp. xi + 440, with 96 diagrams.) Price 20*s*. net.

The Chemical Examination of Water, Sewage, Foods and other Substances. By J. E. Purvis, M.A., University Lecturer in Chemistry and Physics as Applied to Hygiene and Public Health, St. John's and Corpus Christi Colleges, Cambridge, and T. R. Hodgson, M.A., Public Analyst for the County Boroughs of Blackpool and Wallasey. Second and Enlarged Edition. Cambridge: at the University Press, 1922. (Pp. v + 346.) Price 20*s*. net.

An Introduction to the Study of Metallography and Macrography. By Leon Guillet and Albert Portevin. Translated by Leonard Tavener, A.R.S.M., D.I.C. With an Introduction by H. C. H. Carpenter, F.R.S, London: G. Bell & Sons, 1922. (Pp. xvi + 289, with 562 figures.) Price 30*s*. net.

Crystallography and Practical Crystal Measurement. By A. E. H. Tutton, D.Sc., M.A., F.R.S., A.R C.Sc., Past President of the Mineralogical Society. In Two Volumes. Vol. I, Form and Structure; Vol. II, Physical and Chemical. London: Macmillan Co., St. Martin's Street, 1922. (Vol. I, pp. xvii + 746, with 589 figures; Vol. II, pp. viii + 749–1446, with figures 590–931.) Price 30*s*. net each volume.

Earth Evolution and its Facial Expression. By William Herbert Hobbs, Professor of Geology and Director of the Geological Laboratory, University of Michigan. New York: The Macmillan Company, 1921. (Pp. xvii + 178, with 84 figures.) Price 15*s*. net.

Early British Trackways, Moats, Mounds, Camps, and Sites. By Alfred Watkins, Fellow and Progress Medallist of the Royal Photographic Society. Hereford: The Watkins Meter Co.; London: Simpkin Marshall, Hamilton, Kent & Co. (Pp. 40, with 20 plates.) Price 4*s*. 6*d*. net.

General Economic Geology. A Textbook by William Harvey Emmons, Ph.D. New York: McGraw Hill Book Company, 370 Seventh Avenue;

and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. xiii + 516, with 257 diagrams.) Price 20*s*. net.

Empire Forestry. Journal of the Empire Forestry Association, Imperial Institute, London, March 1922. Vol. I. London: Macmillan & Co., St. Martin's Street; New York: The Macmillan Company. (Pp. 125.) Price 4*s*. net, or $1.

Basic Slags and Rock Phosphates. By George Scott Robertson, D.Sc., F.I.C., Head of the Chemical Research Division Ministry of Agriculture and Chief Agricultural Analyst for Northern Ireland. With a Preface by Edward J. Russell, D.Sc., F.R.S., Director of the Rothamsted Experimental Station. Cambridge: at the University Press, 1922. (Pp. xv + 112, with 8 plates.) Price 14*s*. net.

The Fundamentals of Fruit Production. By Victor Ray Gardiner, Frederick Charles Bradford, and Henry Daggett Hooker, junr., of the Department of Horticulture of the University of Missouri. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. xvi + 686.) Price 22*s*. 6*d*. net.

Practical Plant Biology: A Course of Elementary Lectures on the General Morphology and Physiology of Plants. By Henry H. Dixon, Sc.D., F.R.S., Professor of Botany in the University of Dublin. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4. (Pp. xi + 291, with 94 illustrations.) Price 6*s*. net.

Isotopes. By F. W. Aston, M.A., D.Sc., A.I.C., F.R.S., Fellow of Trinity College, Cambridge. London: Edward Arnold & Co., 1922. (Pp. viii + 152.) Price 9*s*. net.

Heredity in the Light of Recent Research. By the late L. Doncaster, Sc.D., F.R.S., Fellow of King's College, Cambridge. Cambridge: at the University Press, 1921. (Pp. x + 163.) Price 4*s*. net.

Man—the Animal. By W. M. Smallwood, Ph.D., Harvard, Professor of Comparative Anatomy in Syracuse University. New York: The Macmillan Company, 1922. (Pp. xv + 223, with 31 figures.) Price 12*s*. net.

Catalogue of the Fossil Bryozoa (Polyzoa) in the Department of Geology, British Museum (Natural History). The Cretaceous Bryozoa (Polyzoa). Vol. IV, The Cribrimorphs—Part II. By W. D. Lang, Sc.D., F.G.S. London: Printed by Order of the Trustees, 1922. (Pp. xii + 404, with 8 plates.) Price £1 12*s*. 6*d*.

The Biology of the Sea-shore. By F. W. Flattely, Lecturer in Zoology, University of Durham, and C. L. Walton, M.Sc., University College of North Wales, Bangor. With an Introduction by J. Arthur Thomson, M.A., LL.D., Professor of Natural History in the University of Aberdeen. London: Sidgwick & Jackson, 1922. (Pp. xvi + 336, with 23 figures and 16 plates.) Price 16*s*. net.

Electrical Engineering Testing: A Practical Work on Continuous and Alternating Currents for Second and Third Year Students and Engineers. By G. D. Aspinall Parr, M.Sc., M.Inst.E.E., A.C.G.I. Fourth Edition, revised and enlarged. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1922. (Pp. xii + 691, with 295 figures.) Price 16*s*. net.

The Failure of Metals under Internal and Prolonged Stress: A General Discussion held jointly by the Faraday Society, the Institution of Mechanical Engineers, the Iron and Steel Institute, the Institute of Metals, North-East Coast Institution of Engineers and Shipbuilders, West of Scotland Iron and Steel Institute, and the Institution of Engineers and Shipbuilders in Scotland, on Wednesday, April 6, 1921, in the hall of the Institution of Mechanical Engineers. Edited by F. S. Spiers, O.B.E., B.Sc., F.Inst.P., Secretary and Editor of the Faraday Society. London: The Faraday Society, 10 Essex Street, W.C.2, 1921. (Pp. v + 215.) Price 10*s*. 6*d*. net.

Protective Relays: their Theory, Design, and Practical Operation. By Victor Todd. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. xii + 274, with 242 figures.) Price 12*s.* 6*d.* net.

Construction: Cost, Keeping and Management. A Treatise for Engineers, Contractors, and Superintendents engaged in the Management of Engineering Construction. By Halbert Powers, Gillette and Richard T. Dana. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. xvii + 572.) Price 25*s.* net.

The Airplane Engine. By Lionel S. Marks, B.Sc., M.M.E. New York: McGraw-Hill Book Company, 370 Seventh Avenue: and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. ix + 454.) Price 30*s.* net.

Mechanical Testing: a Treatise in Two Volumes. By R. G. Batson, Mr. M.Inst.C.E., M.I.Mech.E., Associate of King's College, London, and J. H. Hyde, A.M.Inst.C.E., M.I.A.E., A.M.I.Mech.E. Vol. I, Testing of Materials of Construction. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1922. (Pp. xiii + 413, with 256 figures.) Price 21*s.* net.

Analogies Mécaniques de l'Électricité. By J. B. Pomey. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1921. (Pp. xvi + 149.) Price 15 frs.

Problèmes et exercices d'électricité générale. Par P. Janet, Professeur à la Faculté des Sciences de l'Université de Paris. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1921. (Pp. vii + 254.)

Notes and Examples on the Theory of Heat and Heat Engines. By John Case, M.A. Cambridge: W. Heffer & Sons, 1922. (Pp. iv + 138.) Price 7*s.* 6*d.* net.

Analytical Mechanics for Engineers. By Fred B. Seely, M.S., Associate Professor of Theoretical and Applied Mechanics, and Newton E. Ensign, A.B., B.S., Associate in Theoretical and Applied Mechanics, University of Illinois. New York: John Wiley & Sons; London: Chapman & Hall, 1921. (Pp. xiv + 486, with 454 figures.) Price 24*s.* net.

Model Questions and Answers on the Thermionic Valve. Compiled by Clifford Jones, Principal of the North-Eastern School of Wireless Telegraphy, Newcastle-on-Tyne. Glasgow: James Munro & Company, Marine Engineering and Nautical Publishers. (Pp. 44.) Price 2*s.* 6*d.* net.

Modern Practice in Heat Engines. By Telford Petrie, M.Sc., A.M.I.Mech.E. London: Longmans, Green & Co., 39 Paternoster Row, 1922. (Pp. x + 264, with 111 illustrations and 2 plates.) Price 15*s.* net.

Mechanical Stokers, including the Theory of Combustion of Coal. By Joseph G. Worker, B.S., Secretary of the Stoker Manufacturers' Association of the United States, and Thomas A. Peebles, B.S., Member of American Society of Mechanical Engineers. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. xiii + 258, with 109 illustrations.) Price 15*s.* net.

The Principles of Mechanical Refrigeration: a Study Course for Operating Engineers. By H. J. Macintire, S.S., M.M.E. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. viii + 252, with 114 figures.) Price 12*s.* 6*d.* net.

The Analysis of Fuel, Gas, Water, and Lubricants. By S. W. Parr. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. xii + 250, with 54 diagrams.) Price 12*s.* 6*d.* net.

Human Traits and their Social Significance. By Irwin Edman, Ph.D., Instructor in Philosophy, Columbia University. London: Constable & Co. (Pp. xi + 467.) Price 15*s.* net.

System Building and Constructive Accounting. By Raymond D. Willard, B.C.S. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 & 8 Bouverie Street, E.C.4, 1922. (Pp. viii + 307.) Price 20*s*. net.

The Science of Everyday Life. By Edgar F. Van Buskirk, A.M., and Edith Lillian Smith, A.B. London: Constable & Co. (Pp. xv + 416, with 196 figures.) Price 7*s*. net.

La dialectique du monde sensible. Par Louis Lavelle, Docteur ès Lettres, Professeur au Lycée Fustell de Coulanges à Strassbourg. Publications de la Faculté des Lettres de l'Université de Strassbourg. Fascicule 4. Strassbourg: Commission des Publications de la Faculté des Lettres, Palais de l'Université, 1921; and London: Oxford University Press, Amen Corner, E.C.4. (Pp. xliv + 229.) Price 6*s*. net.

Perception visuelle de la profondeur. Par Louis Lavelle, Docteur ès Lettres, Professeur au Lycée Fustell de Coulanges à Strassbourg. Strassbourg: Commission des Publications de la Faculté des Lettres, Palais de l'Université, 1921; and London: Oxford University Press, Amen Corner, E.C.4. (Pp. 73.) Price 2*s*. net.

Psychology: a Study of Mental Life. By Robert S. Woodworth, Ph.D., Professor of Psychology in Columbia University. London: Methuen & Co., 36 Essex Street, W.C. (Pp. x + 580.) Price 8*s*. 6*d*. net.

Evolutionary Naturalism. By Roy Wood Sellars, Ph.D., Associate Professor of Philosophy in the University of Michigan. Chicago and London: The Open Court Publishing Company, 1922. (Pp. xiii + 343.) Price 12*s*. 6*d*. net.

The Foundations of Japan: Notes made during journeys of 6,000 miles in the rural districts as a basis for a sounder knowledge of the Japanese people. By J. W. Robertson Scott. London: John Murray, Albemarle Street, W., 1922. (Pp. xx + 446, with 85 illustrations.) Price 24*s*. net.

Aspects of Death and Correlated Aspects of Life in Art, Epigram, and Poetry. Contributions towards an Anthology and an Iconography of the Subject. Illustrated especially by Medals, Engraved Gems, Jewels, Ivories, Antique Pottery, etc. By Frederick Parkes, Weber, M.A., M.D., F.R.C.P., F.S.A. Fourth Edition, revised and much enlarged. London: T. Fisher Unwin, Ltd., Adelphi Terrace, 1922. (Pp. xliv + 851.) Price 30*s*. net.

The Population Problem: a Study in Human Evolution. By A. M. Carr-Saunders. Oxford: at the Clarendon Press, 1922. (Pp. 516.) Price 21*s*. net.

Bantu Beliefs and Magic, with Particular Reference to the Kikugu and Kamba Tribes of Kenya Colony; together with some Reflections on East Africa after the War. By C. W. Hobley, C.M.G., M.R.Anthrop. Inst., C.M.Z.S., Assoc.M.Inst.C.E. With an Introduction by Sir James G. Fraser, F.R.S., etc. London: H. F. & G. Witherby, 326 High Holborn, W.C., 1922. (Pp. 312, with 16 illustrations.) Price 18*s*. net.

The Manufacture of Pulp and Paper: a Textbook of Modern Pulp and Paper Mill Practice. Vol. III. By H. N. Lee, A.M., and others. New York: McGraw-Hill Book Company, 370 Seventh Avenue; and London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. xii + 60, with diagrams.) Price 25*s*. net.

The American Indian: An Introduction to the Anthropology of the New World. By Clark Wissler, Curator of Anthropology in the American Museum of Natural History, New York City. Second Edition. New York and London: Oxford University Press. (Pp. xxi + 474, with 82 illustrations.) Price 24*s*. net.

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# SCIENCE PROGRESS

## RECENT ADVANCES IN SCIENCE

**MATHEMATICS.** By F. PURYER WHITE, M.A., St. John's College, Cambridge.

MAX NOETHER, who died in Erlangen on December 13, 1921, is well known for his work on algebraic geometry and the theory of functions and his report, in collaboration with Brill, on the development of that theory, published by the *Deutsche Mathematiker Vereinigung* in 1894. Accounts of his work are given by the Editors of the *Mathematische Annalen* (**85**, 1922), by G. Castelnuovo (*Rend. Lincei*, **31**, 1922, 404–7), and by L. Berzolari (*Rend. Lombardo*, **54**, 1921, 600–3).

Notices of the work of Camille Jordan (d. January 21, 1922) appear in *Nature* (**109**, 1922, 349), and in *Rend. Lincei* (**31**, 1922, 398–404).

George Ballard Mathews, F.R.S. (d. March 19, 1922) is appreciated in *Nature* (**109**, 1922, 450), to which he contributed many striking reviews; an article of his, on "Mathematics and Public Opinion," appears in a later number of the same journal (p. 520).

Sir Alfred Bray Kempe, F.R.S., is chiefly known as a mathematician in connection with linkages; an obituary notice appears in *Nature* (**109**, 1922, 588).

There is a further notice of C. T. Reye by C. Segre (*Rend. Lincei*, **31**, 1922, 269–72).

*History.*—H. Lebesgue, in his inaugural lecture at the Collège de France (*Revue scientifique*, **60**, 1922, 249–62), gives an account of four of his predecessors in the chair, Humbert, Jordan, Roberval and Ramus.

In the fourteenth report on the publication of the Collected Works of Gauss, F. Klein (*Math. Ann.*, **85**, 1922, 326–8) calls attention to the discovery of letters at Copenhagen and of a MS. at Rome.

*Logic, etc.*—D. Hilbert (*Hamburg Seminar*, **1**, 1922, 157–77), in an article, "Neubegründung der Mathematik," combats the views of Weyl and Brouwer.

A. Schoenflies (*Math. Ann.*, **85**, 1922, 60–4) continues his work on the axioms of the theory of aggregates.

*Algebra and Analysis.*—C. Lallemand (*C.R.*, **174**, 1922, 82, 253) gives an account of the development and the present state of nomography; other papers on the subject are by D'Ocagne (*ibid.*, 146, 1664), and by W. Margoulis (*ibid.*, 1684).

M. Lecat (*C.R.*, **174**, 1922, 728) has a note on cubical determinants.

G. Andreoli (*Rend. Napoli*, **27**, 1921, 280–7) determines a class of determinants which can be decomposed into factors involving radicals, and thus a class of algebraical equations solvable by radicals.

P. Levy (*C.R.*, **174**, 1922, 855, 1682) and J. W. Lindeberg (*ibid.*, 1400) discuss the part played by Gauss's law in the theory of errors.

O. Perron (*Sitz. Heidelberg*, 1921, Abh. 4 and 8) discusses the approximation to irrational numbers by rational numbers; and G. Valiron (*C.R.*, **174**, 1922, 1530) Hermite's approximations to an irrational.

M. Auric (*C.R.*, **174**, 1922, 24, 145, 279, 439), in a series of notes, gives a generalisation of continued fractions, with applications.

E. Noether (*Math. Ann.*, **85**, 1922, 26–33), P. Furtwängler (*ibid.*, 34–40), and A. Ostrowski (*Math. Zs.*, **12**, 1922, 317–22) are concerned with the ordinary and absolute irreducibility of algebraic polynomials.

F. S. Macaulay (*Proc. L.M.S.*, **21**, 1922, 14–21) has a note on the resultant of a number of polynomials of the same degree.

G. Szegö (*Math. Zs.*, **13**, 1922, 28–55), following J. H. Grace, and A. J. Kempner (*Math. Ann.*, **85**, 1922, 49–59) deal with the distribution of the complex roots of algebraic equations.

S. Breuer (*Math. Ann.*, **86**, 1922, 108–13) investigates cyclic equations of the sixth degree.

E. Hellinger (*Math. Ann.*, **86**, 1922, 18–29) applies the theory of systems of equations with infinitely many unknowns to Stieltjes' continued fractions.

The ordinary extension of the invariant theory of binary forms is to ternary forms, but another way is to consider several series of variables, giving them independent linear transformations. E. Schwartz (*Math. Zs.*, **12**, 1922, 18–35) does this for the form $P = (ax)(\beta y)$, with a geometrical interpretation in space of seven dimensions.

M. Janet (*C.R.*, **174**, 1922, 432, 991) obtains invariant canonical forms for algebraic systems.

In a report on the theory of divergent series, W. A. Hurwitz (*Bull. Amer. Math. S.*, **28**, 1922, 17–36) gives special attention to the mutual consistency of two summations, *i.e.* whether they give the same value.

T. Carleman (*C.R.*, **174**, 1922, 1527) finds conditions under which a function is determined uniquely by its asymptotic series.

G. Mignosi (*Rend. Napoli*, **27**, 1921, 17–28) and M. Cipolla (*ibid.*, 28–37) give criteria for convergence of series related to those of Hardy; and C. Severini (*Rend. Lincei*, **31**, 1922, 97–101) gives criteria for the uniform convergence of a sequence convergent *in media.*

Completing the work of Helly and Bray, T. H. Hildebrandt (*Bull. Amer. Math. S.*, **28**, 1922, 53–8) finds necessary and sufficient conditions for the convergence of sequences of linear operations.

L. Bieberbach (*Math. Ann.*, **85**, 1922, 141–8) writes on the distribution of the points at which an analytic function takes the values zero or unity; E. Landau (*ibid.*, 158–60) shortens his work. Allied questions are dealt with by P. Montel (*C.R.*, **174**, 1922, 22, 143; *Mem. soc. roy. d. Belgique*, **6**, 1922, fasc. 15) in his papers on quasi-normal families of functions; see also T. Varopoulos (*C.R.*, **174**, 1922, 272).

S. Sarantopoulos (*C.R.*, **174**, 1922, 591) and P. Montel (*ibid.*, 850, 1220) give theorems fixing an upper limit to the moduli of zeros of polynomials subject to certain conditions.

If a polynomial have only real zeros, all its derivatives have only real zeros; G. Polya (*Math. Zs.*, **12**, 1922, 36–60) examines other classes of functions with this property.

As far back as 1894, Borel introduced a class of functions, called quasi-analytic, for which the Taylor expansion diverges at every point, but which are entirely determined by the knowledge of their derivatives at a point. A. Denjoy (*C.R.*, **173**, 1921, 1329) fills a gap in the theory by giving simple criteria for such quasi-analytic properties, and, as a result, several notes on the subject have appeared: E. Borel (*C.R.*, **173**, 1921, 1431; **174**, 1922, 505), M. Gevrey (*ibid.*, 368), G. Julia (*ibid.*, 370), T. Carleman (*ibid.*, 373, 994).

J. Wolff (*C.R.*, **173**, 1921, 1327), A. Denjoy (*C.R.*, **174**, 1922, 95) and T. Carleman (*ibid.*, 588) discuss functions defined by series of rational fractions.

E. H. Moore (*Math. Ann.*, **86**, 1922, 30–9) gives a generalisation of power series in a denumerably infinite system of variables.

Various papers on the singularities of power series and Dirichlet series are by O. Szasz (*Math. Ann.*, **85**, 1922, 99–110), by G. Szegö (*Sitz. Berlin*, 1922, 88–91); by G. Polya (*Proc. L.M.S.*, **21**, 1922, 22–38) on series with integral coefficients; by F. Carlson and E. Landau (*Göttingen Nach.*, 1921, 184–8) and L. Neder (*Math. Ann.*, **85**, 1922, 111–14) on the extension of Fabry's gap-theorem.

T. Varopoulos (*C.R.*, **174**, 1922, 89, 1323) and S. Sarantopoulos (*ibid.*, 1320) study increasing functions; and R. Nevanlinna (*ibid.*, 1325) the relations between the order of growth of a function and the density of its zeros.

G. Valiron (*C.R.*, **174**, 1922, 1054) has a note on integral functions of integral order.

Dirichlet, in his theory of Fourier series, did not, of course, consider *uniform* convergence, and the more recent theories, of Heine, Cantor and Du Bois Reymond, proceed on different lines; C. Neumann (*Leipzig Ber.*, **73**, 1921, 201–14) modifies Dirichlet's theory to fill the gap.

N. Abramescu (*Rend. Lincei*, **31**, 1922, 89, 152, 197) deals with the series of polynomials known as Darboux series.

G. Szegö (*Math. Ann.*, **82**, 1921, 188–212; *Math. Zs.*, **12**, 1922, 61–94) examines the convergence of orthogonal developments of functions; S. Banach (*Proc. L.M.S.*, **21**, 1922, 95–7) gives an example of such a development whose sum is everywhere different from the developed function.

T. Carleman (*C.R.*, **174**, 1922, 1680) investigates a non-decreasing function $\phi(x)$ satisfying the relations

$$\int_{-\infty}^{\infty} x^{\nu} d\phi(x) = C_{\nu} \quad (\nu = 0, 1, 2 \ldots),$$

where $C_0, C_1 \ldots$ is a given sequence of real constants; this is a generalisation of Stieltjes' problem of moments.

L. Fejer (*Math. Ann.*, **85**, 1922, 41–8) investigates the zeros of polynomials which arise from minimum conditions, *e.g.* the Tschebychef and Legendre polynomials; A. Angelesco (*C.R.*, **174**, 1922, 273) generalises the theory of the zeros of orthogonal polynomials, and G. Szegö (*Math. Ann.*, **86**, 1922, 114–39) examines their asymptotic expressions.

A. Angelesco (*Rend. Lincei*, **31**, 1922, 236–9) also writes on the Laguerre polynomials.

E. L. Ince (*Proc. Camb. Phil. S.*, **21**, 1922, 117–20) shows that the second solutions of Mathieu's equation cannot be periodic.

P. Humbert (*C.R.*, **174**, 1922, 91) examines solutions of Laplace's equation in four variables applicable to hyper-cylinders having for base hyperboloids of revolution; he thus obtains Mathieu functions in two variables.

P. J. Myrberg (*C.R.*, **174**, 1922, 1402) examines the essential singularities of automorphic functions of several variables.

G. Mittag-Leffler (*C.R.*, **174**, 1922, 789) and E. Goursat (*ibid.*, 836) continue their priority dispute concerning the proof of Cauchy's theorem.

N. E. Nörlund (*C.R.*, **174**, 1922, 919) has a note on the convergence of Stirling's interpolation series.

A. R. Forsyth (*Proc. Roy. Soc. Edin.*, **42**, 1922, 147–212) discusses in great detail the concomitants of quadratic differential forms in four variables.

G. Ricci (*Rend. Lincei*, **31**, 1922, 65–71) gives conditions for a quadratic differential form in $n$ variables to be reducible so as to contain only the differentials of $n-p$ independent variables.

R. Lagrange (*C.R.*, **173**, 1921, 1325 ; **174**, 1922, 521, 658) makes some applications of the absolute differential calculus ; and J. Lipka (*Rend. Lincei*, **31**, 1922, 242–5) discusses the systems E. H. Villat (*C.R.*, **174**, 1922, 656) discusses the conformal representation of the half plane on a region for which two portions of the frontier can be brought into coincidence by a simple translation.

G. Julia (*C.R.*, **174**, 1922, 517, 653, 800) applies conformal representation to the study of functional equations.

S. Minetti (*Rend. Lincei*, **31**, 1922, 12, 202) studies the functional equation $f(x+y) = f(x)f(y)$ ; and H. Mineur (*C.R.*, **174**, 1922, 1678) certain other algebraic functional equations.

Papers on integral equations are by A. Vergerio (*Rend. Lincei*, **31**, 1922, 15, 49), G. Usai (*Rend. Lombardo*, **54**, 1921, 477–89), G. Andreoli (*Rend. Napoli*, **27**, 1921, 71–5), and I. Fredholm (*C.R.*, **174**, 1922, 980).

H. Geiringer (*Math. Zs.*, **12**, 1922, 1–17) and O. D. Kellogg (*Math. Ann.*, **86**, 1922, 14–17) discuss the characteristic functions of self-adjoint linear differential equations ; G. Andreoli (*Rend. Napoli*, **27**, 1921, 135, 149) generalisations of Riccati's equation ; J. Sommer (*Math. Ann.*, **85**, 1922, 65–73) what is the significance of the 'degree' of a differential equation ; and A. Cahen (*C.R.*, **174**, 1922, 276) first order equations with fixed critical points.

J. Drach (*C.R.*, **174**, 1922, 797) determines second order equations which are integrable by quadratures. W. L. Hart (*Amer. Journ. Math.*, **43**, 1921, 226–31) writes on the Cauchy-Lipschitz method for infinite systems of differential equations.

E. Hilb (*Math. Ann.*, **85**, 1922, 89–98) solves linear difference equations by means of differential equations of infinitely high order.

R. D. Carmichael (*Amer. Journ. Math.*, **43**, 1921, 232–70) continues his systematic treatment of transcendental problems as limiting cases of algebraic problems (see SCIENCE PROGRESS, **63**, 1922, 351).

K. Popoff (*C.R.*, **174**, 1922, 731) considers linear partial differential equations of the second order of elliptic type ; G. Giraud (*ibid.*, 853) non-linear equations ; M. Gosse (*ibid.*, 1612) equations integrable by Darboux's method ; and M. Riquier (*ibid.*, 1392, 1517, 1604) systems of the first order to which Jacobi's method applies.

See also, on first order equations, L. Koenigsberger (*Sitz. Heidelberg*, 1921, Abh. 2 and 7).

W. Sternberg (*Math. Ann.*, **86**, 1922, 140–53) writes on the asymptotic integration of partial differential equations involving a parameter.

If in a problem of the maxima and minima of a function of two variables with the condition that another function is to have an assigned value we interchange the rôles of the two functions, it may happen that the solution is the same with the interchange of maximum and minimum ; J. K. Whittemore (*Amer. Journ. Math.*, **43**, 1921, 271–90) examines this reciprocity

C. Carathéodory (*Math. Ann.*, **85**, 1922, 78–88) and M. Picone (*Rend. Lincei*, **31**, 1922, 46, 94) write on the calculus of variations for multiple integrals.

A. E. Western (*Proc. Camb. Phil. S.*, **21**, 1922, 108–9) compares Hardy and Littlewood's conjectured formula for the number of primes of the form $n^2 + 1$ with the facts as given in tables of Lt.-Col. A. Cunningham up to $n = 15{,}000$.

G. Torelli (*Rend. Napoli*, **27**, 1921, 262–8) and P. Stäckel and W. Weinreich (*Abh. d. Heidelberg. Akad.*, 1922, Abh. 10) write on the representation of an even number as the sum of two primes.

G. H. Hardy and J. E. Littlewood (*Proc. L.M.S.*, **21**, 1922, 39–74) study the zeta-function in the critical strip, and obtain a new result in the order of the error term in the divisor problem.

S. Wigert (*Proc. Camb. Phil. S.*, **21**, 1922, 17–21), C. Siegel (*Math. Ann.*, **85**, 1922, 123–8) and H. Hamburger (*ibid.*, 129–40) also write on the Riemann zeta-function.

Papers on Waring's problem are by H. Weyl (*Göttingen Nach.*, 1921, 189–92), G. H. Hardy and J. E. Littlewood (*Math. Zs.*, **12**, 1922, 161–88), E. Landau (*ibid.*, 219–47) and E. Kamke (*ibid.*, 323–8).

G. H. Hardy and J. E. Littlewood (*Proc. Camb. Phil. S.*, **21**, 1922, 1–5) have a note on the trigonometrical series associated with the elliptic theta-functions ; E. T. Bell (*Math. Zs.*, **13**, 1922, 146–52) gives arithmetical equivalents for an identity between theta-functions ; I. Schur (*Göttingen Nach.*, 1921, 147–53) writes on Gauss's sums, and G. Herglotz (*Leipzig Ber.*, **73**, 1921, 271–6) on the last entry in Gauss's *Tagebuch*, concerned with the connection between the theory of biquadratic residues and the lemniscate functions.

Connected with the theory of algebraic numbers are papers by I. Schur (*Sitz. Berlin*, 1922, 145–68 ; *Math. Zs.*, **12**, 1922, 95–113) ; G. Herglotz (*ibid.*, 255–61) ; E. Hecke (*Hamburg Seminar*, **1**, 1922, 102–12) ; T. Nagel (*ibid.*, 140–50) ; K. Hensel

(*Math. Ann.*, **85**, 1922, 1–10) and A. M. Bedarida (*Rend. Lincei*, **31**, 1922, 5–8).

*Geometry.*—H. Liebmann (*Math. Ann.*, **85**, 1922, 172–6) proves that besides displacements there are no projective transformations of the hyperbolic plane which transform proper points into proper points.

H. Mohrmann (*ibid.*, 177–83) gives examples of non-Desarguesian geometry in the plane ; and M. Dehn (*ibid.*, 184–94) writes on the principle of duality in non-Archimedean geometry.

C. M. Sparrow (*Amer. Journ. Math.*, **43**, 1921, 222–5) discusses the Fermat and Hessian points of the non-euclidean triangle ; C. Servais (*Bull. d. Belgique*, **7**, 1921, 641–52 ; **8**, 1922, 62, 103) writes on the geometry of the tetrahedron ; and F. Schottky (*Sitz. Berlin*, 1922, 173–81) gives theorems about points on an ellipse which include Graves's and MacCullagh's.

F. Schilling (*Math. Ann.*, **85**, 1922, 200–7) gives a space generalisation of the Peaucellier cell, and F. H. Murray (*C.R.*, **174**, 1922, 1399) describes an instrument of manageable size by means of which arcs of very large circles may be drawn accurately.

F. Enriques (*Math. Ann.*, **85**, 1922, 195–9) shows how results in the geometry on an algebraic curve may be obtained from consideration of the degenerate case in which the curve is rational.

H. Hilton (*Proc. L.M.S.*, **21**, 1922, 1–13) discusses plane curves of degree $2n$ with tangents having bi-$n$-point contact ; F. V. Morley (*ibid.*, 140–60) gives an analytical treatment of the 3-bar curve ; and W. P. Milne (*ibid.*, 134–9) proves a theorem of Morley's on apolarity by means of cubic surfaces.

M. Castellani (*Rend. Lincei*, **31**, 1922, 347–50), defining the osculating space of a surface as the least space which contains the osculating planes of all curves through the point, investigates surfaces whose osculating spaces are bi-osculating.

D. Montesano (*Rend. Napoli*, **27**, 1921, 116, 164) and L. Godeaux (*Mém. d. Belgique*, **6**, 1922, fasc. 12) discuss birational transformations in space.

F. Sibirani (*Rend. Lombardo*, **54**, 1922, 404–13) writes on line congruences of equal slope ; and E. Veneroni (*ibid.*, 383–94) on congruences of conics.

E. Study (*Math. Ann.*, **86**, 1922, 40–77), in his usual polemical style, sets out to reduce to order Lie's sphere geometry.

E. Vessiot (*C.R.*, **174**, 1922, 989–91) studies properties of systems of circles which are not altered by conformal transformations.

E. H. Neville (*Proc. Camb. Phil. S.*, **21**, 1922, 97–107) improves de la Vallée Poussin's definition of an envelope.

G. Herglotz (*Leipzig Ber.*, **73**, 1921, 215–25), G. Fubini (*Math. Ann.*, **85**, 1922, 213–21), J. A. Schouten (*Math. Zs.*, **13**, 1922, 56–81) and A. Finzi (*Rend. Lincei*, **31**, 1922, 8–12) write on differential geometry in *n* dimensions.

J. Lipka (*Rend. Lincei*, **31**, 1922, 353–6) and A. Myller (*C.R.*, **174**, 1922, 997–9) use Levi-Civita's theory of parallelism respectively to define geodesic curvature and to obtain properties of ruled surfaces.

Sophus Lie showed how to determine all *translation-surfaces* in three-dimensional space; B. Gambier (*C.R.*, **174**, 1922, 98–100) points out that his method does not give all possible surfaces of this kind in space of more dimensions.

H. Liebmann (*Sitz. Heidelberg*, 1921, Abh. 5; *Math. Zs.*, **13**, 1922, 10–17) discusses surfaces of constant curvature.

E. J. Wilczynski (*Math. Ann.*, **85**, 1922, 208–12) gives an account of the work of G. M. Green and himself on the geometrical significance of isothermal conjugacy of a net of curves on a surface.

B. Gambier (*C.R.*, **174**, 1922, 523, 661, 1613) considers point transformations between two surfaces connected with their fundamental quadratic forms; *e.g.* such that conjugate nets on one become orthogonal nets on the other.

He also investigates (*C.R.*, **174**, 1922, 921–4) isothermal surfaces of which the spherical representation is isothermal.

H. Jonas (*Math. Ann.*, **86**, 1922, 78–98) considers the deformation of line congruences.

Beginning in 1916, a series of memoirs have appeared, first in the *Leipzig Berichte*, and then in the *Mathematische Zeitschrift* and the *Abhandlungen* of the recently founded mathematical *Seminar* at Hamburg, bearing the general title of: "Über affine Geometrie." They deal with properties which are invariant under the group of affine transformations of determinant unity; the inspirer of the series, W. Blaschke, promises a connected account of the subject in the second volume of his *Vorlesungen über Differentialgeometrie*, of which the first has recently appeared. The latest memoirs are by W. Blaschke (*Math. Zs.*, **12**, 1922, 262–73; *Hamburg Seminar*, **1**, 1922, 151–6) on the analogues in affine geometry to minimal surfaces and the non-deformability of the sphere; by A. Winternitz (*ibid.*, 99–101) and by K. Reidemeister (*ibid.*, 127–39).

## APPLIED MATHEMATICS.

By S. Brodetsky, M.A., Ph.D., F.Inst.P., D.Sc., University, Leeds.

Henri Poincaré died in 1912, leaving behind a legacy of scientific achievement of remarkable extent and versatility. The pure mathematician, the applied mathematician, the astronomer, the physicist, and even the philosopher, have derived considerable benefit from the fertile mind and mathematical ability of this most distinguished product of French genius. *Acta Math.*, **38**, 1921, 1–402, consists of an appreciation of Poincaré's work, entitled " Henri Poincaré, in Memoriam." The applied mathematician will be particularly interested in articles by W. Wien : " Die Bedeutung Henri Poincarés für die Physik " ; by H. A. Lorentz : " Deux mémoires de Henri Poincaré sur la physique mathématique " ; by M. Planck : " Henri Poincaré und die Quantentheorie " ; by H. v. Zeipel : " L'œuvre astronomique d'Henri Poincaré." The last article betrays the extraordinary width of Poincaré's interests in dynamical theory and in celestial mechanics, embracing as it did such topics as the tides, figure of the earth, figures of equilibrium of rotating fluids, planetary and lunar theory—with the famous Poincaré's theorem on the integrals of the restricted problem of three bodies—besides mathematical methods of great importance in modern dynamical theory, like integral invariants, etc. An interesting feature of this issue of the *Acta* is an analysis of Poincaré's works, written by himself. There is no biography—which is a pity—but an excellent portrait is added to this appreciation of Poincaré's labours in the various domains of the exact sciences. Although it was ready in 1916, the volume could not be issued till last year, owing to difficulties caused by the war.

Poincaré was among the earliest to recognise the far-reaching importance of the views contained in Einstein's first papers on relativity. When Einstein was appointed professor at Zürich, Poincaré wrote of him as one of the most original thinkers he had ever known : " What we most admire in him is the ease with which he assimilates new conceptions, and deduces from them all their consequences." It is therefore the more interesting to witness the reception given to Einstein's theories by the French mathematicians and physicists, most of whom, no doubt, were profoundly influenced by the views and methods of their great compatriot.

French scientists are in fact engaged in exhaustive and critical study of the foundations and consequences of the theory of relativity. Occasionally the criticism is somewhat unscientific in temper, as in the case of M. Gandillot, who commences the preface to the booklet called " Éther ou Relativité " (Gauthier Villars, Paris, 1922) in the following manner : " Voltaire, who knew the Germans well as having lived some time in their midst, said that when two Germans converse without understanding one another, then they are talking metaphysics ; but when the conversation reaches such heights that each one does not understand himself, then they are talking high metaphysics. The generalised theory of relativity seems to be high metaphysics enshrined in imposing algebra. . . ." In the main, however, the examination of the theory is proceeding on lines of sober scientific argument, untainted by prejudices that suggest national differences. Writers like E. Picard, P. Painlevé and others, give us carefully thought out and cautiously expressed statements, which are of great value to such as do wish to understand the theory and its physical consequences.

Of great interest is a further paper by P. Painlevé (*Comptes Rendus*, **174**, 1922, 1137–43), who sets out the fundamental postulates of the classical theory of the Newtonian mechanics, and compares them with those of the Einsteinian theory. In addition Painlevé indicates briefly his own standpoint—one that has much to recommend it in the eyes of the ordinary applied mathematician, who wishes to combine caution with progress. The writer retains the fundamental basis of Euclidean geometry, but postulates that in the neighbourhood of gravitating matter the geometrical properties of solid bodies are changed in accordance with the coefficients in a quadratic differential expression $ds^2$ similar to that underlying Einstein's work. A further communication is promised on the subject.

S. Zaremba (*Journ. de Math. pures et appl.*, (9) I, 1922, 105–39) gives a critical examination of the foundations of the theory. He claims that the consequences that are drawn by relativists from the fundamental postulates of their theory, do not really follow from them. Zaremba holds that the theory needs completion in its essentials, and is somewhat doubtful if this will ever take place. (See also *Comptes Rendus*, **174**, 1922, 1416–18.)

Keen opposition to the theory is again expressed by J. Le Roux (*Comptes Rendus*, **174**, 1922, 924–7, and *Journ. de Math. pures et appl.*, (9) I, 1922, 205–53). The latter paper consists of a discussion of the restricted theory of relativity. Le Roux claims that the Michelson and Morley experiment does not necessarily lead to the modifications of our conceptions of time and space involved in the restricted theory—which in his opinion is quite useless. He examines the mathematics of waves emitted by moving sources and finds that the geometry of the Lorentz transformation is given by what he calls " ellipsoidal interference waves." Le Roux concludes: " Einstein's restricted principle of relativity is either a superfluity or an absurdity, according to the domain of its application." Opposition to the theory is also the burden of a paper by E. Wiechert (*Phys. Zeit.*, xxiii, 1922, 25–8), who is inclined to support the older relativity views of Mach as against Einstein's " Standpunktsrelativität."

On the question whether it is possible to find observational means of discriminating between the classical and the relativity dynamics as applied to planetary motion, other than that referring to the perihelion of mercury, J. Trousset (*Comptes Rendus*, **174**, 1922, 1160–1) shows that apart from the motion of the perihelion of mercury, observational accuracy of one-thousandth of a second of arc would be required in order to distinguish between the gravitational theories of Newton and of Einstein.

The " crucial phenomena " are the subject of further investigations. A paper by L. Lecornu (*Comptes Rendus*, **174**, 1922, 337–42) is mainly an attempt to explain the motion of the perihelion of mercury and the bending of a ray of light moving past the sun, by means of additional forces perpendicular to the path, forces that " can be regarded as manifestations of the presence of the ether, and by means of which astronomical phenomena can be explained . . . without forcing human intelligence to sacrifice its intuitive notions of space and time." It is of interest to note that Lecornu takes the view that the path of a ray of light is also a planetary path. Further, G. Bertrand (*ibid.*, **174**, 1922, 1687–9) shows that by using Riemann's electromagnetic law of action results are obtained for the motion of perihelion and the bending of light similar to Einstein's. M. Ferrier (*ibid.*, **174**, 1922, 1404–7) discusses the explanation of the bending of light by means of an atmosphere on the moon.

Other recent papers that should interest applied mathematicians are :

DIENES, P., Sur la connexion du champ tensoriel, *Comptes Rendus*, **174**, 1922, 1167–70, where the author objects to Weyl's and Eddington's generalised tensorial geometry.

JAFFÉ, G., Bemerkungen über die relativistischen Keplerellipsen, *Ann. der Phys.*, **67**, 1922, 212–26. The author considers the motion of a body of small mass and small charge in the field due to a body of large mass and large charge, on the basis of the general theory of relativity. He explains why we must use the generalised equations in dealing with the motion of the perihelion of mercury, while the restricted theory is sufficient in dealing with the motion of an electron in an atom.

SAGNAC, G., Les invariants newtoniens de la matière et de l'énergie radiante, et l'éther mécanique des ondes variables, *Comptes Rendus*, **174**, 1922, 29–32.

WRINCH, D., The Theory of Relativity in Relation to Scientific Method, *Nature*, **109**, 1922, 381–2.

BRILLOUIN, M., Champ isotrope : Sphère fluide hétérogène, *Comptes Rendus*, **174**, 1922, 1585–9, who extends Schwarzschild's solution of Einstein's equations to the case of a sphere in which the matter is in the form of concentric layers of different densities.

SANGER, M., Sur une coincidence rémarquable dans la théorie de relativité, *ibid.*, **174**, 1922, 1002–3. The coincidence is that Schwarzschild's solution for empty space round a point mass can be derived from the Lorentz transformation.

Cartan, E., Sur une définition géométrique du tenseur d'énergie d'Einstein, *ibid.*, **174**, 1922, 437–9; also 593–5.
Cartan, E., Sur les équations de la gravitation d'Einstein, *Journ. de Math. pures et appl.*, (9) I, 1922, 141–203, mainly of mathematical interest.
Buhl, A., Les théories einsteiniennes et les Principes du Calcul intégral, *ibid.*, (9) I, 1922, 95–104.
Chazy, J., Sur les vérifications astronomiques de la théorie de rélativité, *Comptes Rendus*, **174**, 1922, 1157–60. The author uses the more general equations $G_{\mu\nu} - \lambda g_{\mu\nu} = 0$, and shows that the observed motions of the perihelia of planets leads to the view that the radius of the universe is of the order of 1,000 light-years.

The publication of the second part of U. Cisotti's *Idromeccanica Piana* (Milano, 1922) serves to draw attention to one of the classical problems of hydrodynamics, namely that of discontinuous fluid motion past a plane or a curved barrier. Cisotti's book contains an account of the recent methods for dealing with this problem. These methods are based upon the introduction of such transformations that the barrier becomes a semicircle in an Argand diagram. The transformations were discussed by Levi-Civita in 1906, and they have the great advantage of reducing any such problem with a single barrier in infinite fluid, to a purely mathematical process of finding a Taylor expansion with such coefficients as are suitable to the form of any given barrier. Comparatively simple formulæ exist for the pressure on the barrier, in terms of the coefficients in the above expansion. Cisotti's book explains the general method, and then proceeds to its application to the particular cases of the plane barrier and of the bent-plane barrier, known as the Bobyleff problem. A family of curved barriers due to Brillouin are also discussed, and the integro-differential equation deduced for finding the solution for a barrier given by the radius of curvature in terms of the angle of contingence. The method is extended to a barrier in a canal, and to a barrier in fluid bounded on one side and extending to infinity on the other. The theory of jets is then dealt with in detail.

A recent paper by G. Jaffé (*Phys. Zeit.*, xxiii, 1922, 129–33) raises again an interesting fact discussed by Villat, Thirry, and others. Several years back Villat showed that the usual conventions of the theory of discontinuous fluid motion do not necessarily lead to unique solutions. Thus, if we have a barrier like that of the Bobyleff problem, with concave angle turned towards the streaming fluid, but the ratio of the widths of the two planes not that of Bobyleff's solution, we can get one solution in which the moving fluid is in contact with the whole of the front of the barrier, and another in which there is in front of the barrier a space of fluid at rest bounded by a free stream line, which is tangential to the two planes. Thirry showed that in reality there is a range of possible solutions of this problem, lying between the two extreme solutions as found by Villat. Jaffé now shows that such a range of solutions also exists when the concave angle is turned away from the streaming fluid, and the two planes extend to infinity.

A certain amount of progress is being made with the investigation of the motion of viscous fluids. An interesting attempt at the discussion of a problem that can be of some practical use is by L. Bairstow, B. M. Cave, and E. D. Lang in a paper entitled "The Two-Dimensional Slow Motion of Viscous Fluids," *Proc. Roy. Soc.*, A, **100**, 1922, 394–413. The work is based on the solution of the equation $\Delta^4\psi = 0$ for certain boundary conditions, and in particular the authors find the pressure on a circular cylinder in the middle of a parallel-walled channel whose width is five times that of the cylinder. A problem of more academic interest is investigated by G. B. Jeffery, who deals with the rotation of two circular cylinders in a viscous fluid (*Proc. Roy. Soc.*, A, **101**, 1922, 169–74). Two cases are examined, the first with one cylinder inside the other, the second with both cylinders outside one another.

Recent papers on aerodynamical and hydrodynamical problems are:


Rateau, A., Théorie générale du turbo-compresseur pour moteurs d'avions, *Comptes Rendus*, **174**, 1922, 1511–16.

Rateau, A., Pressions et poids spécifiques de l'air en atmosphère normale, *ibid.*, **174**, 1922, 1598–1604, discussing the variation of air pressure and air density with altitude. The results are applied to the effect on the ceiling of an aeroplane, *ibid.*, **174**, 1922, 1669–74.

Pogezy, E., Sur la forme optimum à donner aux hélices propulsives, *ibid.*, **174**, 1922, 1327–30, giving a correction in Rateau's theory of propellers.

Riach, M. A. S., The Fan Propeller and Blade Interference, *Aer. Jour.*, xxvi, 1922, 63–80, discussing the propeller acting at a fixed point, on the basis of blade interference.

Wieselsberger, C., Weitere Feststellungen über die Gesetze des Flüssigkeits- und Luftwiderstandes, *Phys. Zeit.*, xxiii, 1922, 219–24.

Hankin, E. H., Observations on the Flight of Flying Fishes, *Proc. Zool. Soc. Lond.*, 1920, 467–74.

Boussinesq, J., Aplatissement suivant l'axe polaire, par la tension superficielle, d'une goutte liquide de révolution et sans pésanteur, possédant une vitesse angulaire donnée $\omega$ de rotation autour de cet axe, *Comptes Rendus*, **172**, 1921, 941–6, 1085–6.

Riabouchinski, D., Quelques considérations sur la forme du solide et l'énergie cinétique du fluide qui l'entoure, *ibid.*, **174**, 1922, 212–15.

Havelock, T. H., The Effect of Shallow Water on Wave Resistance, *Proc. Roy. Soc.*, A, **100**, 1922, 499–505.

Schiller, L., Experimentelle Feststellungen zum Turbulenzproblem, *Phys. Zeit.*, xxiii, 1922, 14–19.

Prandtl, L., Bemerkungen über die Entstehung der Turbulenz, *ibid.*, xxiii, 1922, 19–25.

LEVY, H., On the Criterion for Stable Flow of a Fluid in a Uniform Channel, *Proc. Roy. Soc. Edin.*, xli, 1921, 136–47.
RIABOUCHINSKI, D., Sur quelques cas de mouvements planes de fluides autour de solides avec tourbillons, *Comptes Rendus*, **174**, 1922, 1224–7.
AHLBORN, F., Turbulenz und Geschwindigkeitsverteilung in Flussläufen, *Phys. Zeit.*, xxiii, 1922, 57–65.
GREENHILL, G., The Tide in the Bristol Channel, *Proc. Camb. Phil. Soc.*, xxi, 1922, 91, one of whose objects it is to show the advantage of using Fourier's functions, of which $F_n$ (z) is defined by the equation $zy'' + (1 + n) y' + y = 0$.

The teacher of applied mathematics will be interested in a brief paper by A. Dakin, whose aim is well expressed by its title: "That Pure and Applied Mathematics Ought to be Taught and Developed *pari passu* in Boys' Secondary Schools," *Math. Gaz.*, xi, 1922, 51–4. The author mentions an interesting fact, that in public examinations of the School Certificate and Matriculation standard, out of eight candidates taking pure mathematics only one takes applied mathematics or mechanics. Teachers of applied mathematics at universities know how unpopular their subject is among most students, and where students can take pure mathematics alone, the number doing applied mathematics is almost negligible—and this is in spite of the fact that many of the principles of mechanics are taught in courses of physics, so that applied mathematics ought to be almost a "soft option." This reluctance towards the study of mechanics is probably due to the fact that so little is done on the subject at secondary schools, and if Dakin's paper will help to swell the number of candidates taking mechanics or applied mathematics at the School Certificate examinations, it will be an excellent thing for university mathematics departments.

It is of course true that many students find it difficult to take courses in applied mathematics because of the need for independent thought in doing examples in mechanics. Take, for instance, the question of units in dynamics. The student is often in a state of bewilderment, induced by the unpleasant conviction that there is a symbol $g$ which has a habit of getting into the wrong place—and this has been known to happen to some who are past the student stage in the subject. The controversy between the adherents of engineer's and of scientific units, about which considerable heat is often developed (*Nature*, **109**, 1922, 12, 44, 74–5, 139), can have little bearing on this difficulty. Whether we use $g$ as a multiplier and take the weight of a body of mass $m$ lb. to be $mg$ poundals, or we use $g$ as a divisor and take the mass of a body of weight $w$ lb. to be $w/g$ slugs, the difficulty in the student's mind is bound to persist. The experience of the writer of these notes is probably that of many teachers of the subject:

he uses $w$ and $w/g$ in one lecture, and $m$ and $mg$ in an immediately following lecture—the former being in an elementary course, the latter in an honours course.

In a letter to *Nature*, **109**, 1922, 645–7, A. Gray makes some interesting remarks on some well-known elementary propositions in attractions, showing how immediate proofs can be obtained, rigid and complete, but yet almost intuitive. The proof by means of Gauss' theorem that a uniform spherical shell attracts at any outside point like an equal point mass at the centre, is of course the common property of all teachers and most students of the attraction theory. To prove the same for the potential, Gray uses elementary cones through the point where the shell is cut by the radius to the outside point considered, considering the elements of area cut off on the concentric sphere through this point. It is also shown how to apply the method to ellipsoidal shells. Another problem taken is that of the force between the two hemispherical halves of a uniform gravitating sphere. G. Greenhill adds some remarks, *ibid.*, **109**, 1922, 778. One point that has interested the writer of these notes is the following. It is known that an ellipsoidal shell bounded by concentric similar and similarly situated ellipsoids gives zero force inside. Is the ellipsoidal shell the only one possessing this property? In terms of electricity the question is: a charged ellipsoidal conductor, when isolated, has surface density proportional to the perpendicular from the centre on the tangent plane: is there any other form of conductor having this property?

Lambert's theorem in central orbits under the inverse square law has recently been put into a form that leads to a more extended usefulness of the theorem in astronomy (M. Subbotin, *M.N., R.A.S.*, lxxxii, 1922, 383–90, 419–29). The form is

$$\frac{1}{4a}=\frac{\tau}{r+r^1}-\frac{s^2}{\theta^2}$$

where $r, r^1$ are the heliocentric distances of a planet or comet at two instants $t, t^1$, $a$ is the semi-major axis of the path, $s$ is the distance between the positions, and $\theta$ is proportional to $t-t^1$. The quantity $\tau$ is a function of the two quantities $(r+r^1)/4a$ and $s/(r+r^1)$. The advantage of this form is that $\tau$ is in practice very nearly unity, and changes slowly.

An article by A. R. Forsyth: "Differential Equations in Mechanics and Physics" (*Math. Gaz.*, xi, 1922, 73–81), contains many points of interest on the relations between pure and applied mathematics. The author criticises present text-books, where each writer develops the mathematics required as if the methods and processes applied only to this subject, regardless of the fact that the same mathematical methods are required in other branches of mechanics and physics. Forsyth urges the need of an English book like Weber's edition of Riemann's *Partial Differential Equations of Mathematical Physics*, and says: "It would be just a useful treatise of natural philosophy, written by one who knows his mathematics, his mechanics, and specially his physics."

The following papers should be noted:

BUCKINGHAM, E., Notes on the Methods of Dimensions, *Phil. Mag.*, (vi), **42**, 1921, 696–719.

DELASSUE, E., Sur une conséquence des lois de frottement, *Comptes Rendus*, **172**, 1921, 1335–7.

FUCHS, S., Zur Theorie des Gleit- und Rollwiderstandes der festen Körper, *Phys. Zeit.*, xxii, 1921, 173–7, 213–18, where the phenomena of sliding and rolling friction are explained by hydrodynamical suction of the air-layer between the bodies.

FRONTARD, M., Cycloïdes de glissement de terres, *Comptes Rendus*, **174**, 1922, 526–9; see also 740–2, 930–3.

GUILLAUMIN, G., Sur l'équilibre des talus en terre cohérente, *ibid.*, **174**, 1922, 1165–7; see also 1278–80, 1410–13.

RÉMOUNDOS, G., Sur les déformations planes et le problème de la poussée des terres, *ibid.*, **174**, 1922, 929–30; see also E. GOURSAT, *ibid.*, 1049, and G. RÉMOUNDOS, *ibid.*, 1533–4.

WEBSTER, A. G., On Steering an Automobile around a Corner, *Proc. Nat. Acad. Sci., U.S.A.*, **8**, 1922, 100–6, where the path is considered for turning through a right angle without skidding. It is shown that the safe speed is just less than 10 miles per hour.

SEARLE, G. F. C., An Experiment Illustrating the Conservation of Angular Momentum, *Proc. Camb. Phil. Soc.*, xxi, 1922, 75–9.

STOKES, G. D. C., An Analytical Treatment of the Cam Problem, *Proc. Edin. Math. Soc.*, xxxix, 1921, 7–12.

BAKER, W. C., A New Gyroscopic Construction in Simple Vectors, *Phys. Rev.*, xix, 1922, 323–8.

LE ROLLAND, P., Etude de l'oscillation du pendule par le méthode photographique (Influence de la suspension), *Ann. de Phys.*, xvii, 1922, 165–381.

JONES, A. T., The Motion of a Simple Pendulum after the String has become Slack, *Phil. Mag.*, (vi), **41**, 1921, 809–13.

JACKSON, L. C., Variably Coupled Vibrations: Gravity Elastic Combination II. Both Masses and Periods Equal, *Phil. Mag.*, (vi), **40**, 1920, 329–42.

BARTON, E. H., and BROWNING, H. M., Triple Pendulums with Mutual Interaction and the Analogous Electric Circuits, *ibid.*, (vi), **40**, 1920, 611–18; **42**, 1921, 17–34.

MORTON, W. B., and TOBIN, T. C., Notes on Times of Descent under Gravity, suggested by a Proposition of Galileo's, *ibid.*, (vi), **41**, 1921, 225–39.

HARRISON, W. J., Notes on the Theory of Vibrations: (1) Vibrations of Finite Amplitude, (2) A Theorem due to Routh, *Proc. Camb. Phil. Soc.*, xx, 1920, 83–7.

BAKER, B. B., and ROSS, E. B., The Vibrations of a Particle about a Position of Equilibrium, *Proc. Edin. Math. Soc.*, xxxix, 1921, 34–57.

TIERCY, G., Sur les courbes orbiformes. Leur utilisation en mécanique, *Tôh. Math. Jour.*, **18**, 1920, 90–115; the curves are curves of constant width.

UPADHYAYA, P. O., Tautochronous Motion, *ibid.*, **20**, 1921, 32–6.

IWATSUKI, T., On Plane Motions, *ibid.*, **20**, 1922, 131–60.

SUGIHARA, T., Side Thrust due to Obliquity of the Connecting Rod in a High-Speed Reciprocating Engine, *Tech. Rep. Tôh. Imp. Univ.*, ii, 1921, 17–26.

HULBURT, E. O., The Path of a Rigid Electron which moves in a Magnetic Field of Constant Strength Rotating with Constant Angular Velocity, *Phys. Rev.*, xix, 1922, 329–32.

MICHAUD, E., Généralisation du théorème de Reech, nouveaux critères de stabilité et d'instabilité de l'équilibre, *Ann. de Phys.*, xvi, 1921, 131–55.

LIPKA, J., Motion on a Surface for any Positional Field of Force, *Proc. Nat. Acad. Sci., U.S.A.*, **6**, 1920, 621–4.

BUCHANAN, D., Periodic Orbits on a Surface of Revolution, *Amer. Jour. Math.*, xlii, 1920, 47–75.

BIRKHOFF, G. D., Surface Transformations and their Dynamical Applications, *Acta Math.*, **43**, 1920, 1–119.

DARWIN, C. G., The Dynamical Motion of Charged Particles, *Phil. Mag.*, (vi) **39**, 1920, 537–51.

DARWIN, C. G., Lagrange's Methods for High-Speed Motion, *Proc. Camb. Phil. Soc.*, xx, 1920, 56–60, dealing with the complications introduced by changes in mass and retarded potentials.

BILIMOVITCH, A., Sur les équations intrinsèques du mouvement d'un corps solide, *Comptes Rendus*, **171**, 1920, 616–18.

BENNETT, G. T., The Rotation of the Non-Spinning Gyrostat, *Proc. Camb. Phil. Soc.*, xx, 1920, 70–3; see also G. GREENHILL, *ibid.*, xx, 1921, 243–5, and G. T. BENNETT, *ibid.*, 245–6.

FATOU, G., Sur le mouvement d'une planète dans un milieu résistant, *Comptes Rendus*, **174**, 1922, 1162–5, 1330–2, the resistance varying as the velocity. See also J. CHAZY, *ibid.*, 1280–2, who adopts a more general hypothesis of resistance.

GREAVES, W. M. H., The Existence Theorem for certain Periodic Orbits in the Restricted Problem of Three Bodies, *M.N., R.A.S.*, lxxxii, 1922, 134–49.

BECKER, L., Elimination of known Integrals from the *n*-Body Problem, *M.N., R.A.S.*, lxxxi, 1920, 787–91.

CHAZY, J., Sur la stabilité à la Poisson dans le problème des trois corps, *Comptes Rendus*, **173**, 1921, 517–19, 576–8.

CHAZY, J., Sur l'allure du mouvement dans le problème des trois corps quand le temps croit indéfiniment, *ibid.*, **170**, 1920, 1560–3.

GOURSAT, E., Sur la théorie des invariants intégraux, *ibid.*, **174**, 1922, 1089–91.

POTTER, H. H., Note on the Gravitational Acceleration of Bismuth, *Phys. Rev.*, xix, 1922, 187–8, showing that it is the same as for brass, within 1 in 50,000.

WULF, T., Zum Nachweis der Newtonschen allgemeinen Massenziehung, *Phys. Zeit.*, xxiii, 1922, 154–7.

BRIGGS, L. J., Measurement of Gravity at Sea, *Bull. Nat. Res. Council, U.S.A.*, **3**, 1922, 3–11.

LEES, C. H., On the Mechanical Equilibrium of a Sphere of Gravitating Fluid, *Proc. Lond. Phys. Soc.*, xxxii, 265–70, xxxiii, 116–23, dealing with compressible fluid.

GREENHILL, G., The Uniaxial Potential Function and its Orthogonal Force Function contrasted, *Jour. de Math. pures et appl.*, (8) iv, 1921, 155–94.

NICHOLSON, J. W., Problems Relating to a Thin Plane Annulus, *Proc. Roy. Soc.*, A, **101**, 1922, 195–210, taking the annulus to be represented by a thin Elliptic Anchor Ring.

WILKOSZ, W., Sur un point fondamental de la théorie du potential, *Comptes Rendus*, **174**, 1922, 435–7.

EVANS, G. C., Problem of Potential Theory, *Proc. Nat. Acad. Sci., U.S.A.*, **7**, 1921, 89–98.

Bateman, H., Correspondences between Three-Dimensional and Four-Dimensional Potential Functions, *Mess. Math.*, li, 1922, 151–60.

Cowley, W. L., and Levy, H., On a Method of Analysis suitable for the Differential Equations of Mathematical Physics, *Phil. Mag.*, (vi) **41,** 1921, 584–607.

Frary, H. D., The Green's Function for a Plane Contour, *Amer. Jour. Math.*, xlii, 1920, 11–25.

Gevrey, M., Sur la détermination des fonctions de Green, *Comptes Rendus*, **171,** 1920, 610–12.

Humbert, P., L'équation de Laplace en coordinées hypertoroïdales, *ibid.*, **171,** 1920, 1116–19.

Hayashi, T., On Picard's Solution of $\Delta u = k^2 u$, *Sci. Rep. Tôh. Imp. Univ.*, ix, 1920, 295–304.

Hayashi, T., On a certain Differential Equation in Mathematical Physics, *ibid.*, x, 1921, 43–55; the equation is $(1 - x^2)y'' = (a + bx^2)y$.

Pal, B., On the Application of Mathieu Functions to Physical Problems, *Bull. Calc. Math. Soc.*, xii, 1921, 173–82.

Das, P., On the Vibrations of the Pianoforte String, *Proc. Ind. Ass. Sci.*, vii, 1921, 13–20.

Ghosh, R. N., On the Forced Oscillation of Stretched Strings under Damping proportional to the Square of the Velocity, *ibid.*, vi, 1920, 67–86.

Banerji, B., Mechanical Illustration of the Theory of Large Oscillations and Combinational Tones, *ibid.*, vi, 1920, 37–50.

Webster, A. G., On a Condition for Helmholtz's Equation similar to Lamé's, *Proc. Nat. Acad. Sci., U.S.A.*, 1920, 605–7.

Walker, G. T., The Theory of the Flute, *Proc. Ind. Ass. Sci.*, vi, 1921, 113–20.

Chapman, S., and Livens, G. H., The Influence of Diffusion in the Propagation of Sound Waves in Air, *Proc. L.M.S.*, (2) **19,** 1921, 341–9.

Jones, J. E., On the Distribution of Energy in Air surrounding a Vibrating Body, *ibid.*, (2) **20,** 1922, 347–64, dealing with a sphere vibrating in various ways in an infinite medium.

Banerji, S., Note on Spherical Waves of Finite Amplitude, *Bull. Calc. Math. Soc.*, xii, 1921, 189–92.

Dévé, C., Sur les ondes de choc, leur réfraction et leur mirage à l'intérieur d'un courant d'air, *Comptes Rendus*, **171,** 1920, 605–7; see also H. Parenty, *ibid.*, 1190–4.

Milne, E. A., Sound Waves in the Atmosphere, *Phil. Mag.*, (vi) **42,** 1921, 96–114.

## PHYSICS. By J. Rice, M.A., University, Liverpool.

*A Quantum Mechanism in the Atom.*—In Vol. 42 of the *Proc. Roy. Soc. Edin.* there have appeared a group of interesting papers expounding and discussing a mechanism which is capable of giving unreversed action upon an electron in its motion towards and through an atom and which compels all exchanges between the kinetic energy of electrons and radiant energy to conform to the Planck quantum equations. The idea appears to have arisen in the mind of Prof. E. T. Whittaker while listening to an exposition by Sir Alfred Ewing, now Principal of the University of Edinburgh, of a new model which he has proposed to account for ferromagnetic induction. In this address, which is also printed in the same volume of the *Proceedings*, Ewing points out one rather unsatisfactory feature of his former well-known model, which is made up of little magnets pivoted on uniformly spaced fixed centres and all free to turn, but individually controlled by their mutual magnetic forces. It concerns the stability of the rows of magnets in the model when an external magnetic field is applied. Actually when a slowly increasing magnetising field acts on a piece of soft iron, the magnetisation it acquires during the quasi-elastic stage which precedes the appearance of hysteresis is a very small part, often less than 1 per cent., of the intensity acquired at saturation. Hence the range of stable deflection which the " Weber element " in an atom of iron can undergo before instability occurs is very narrow, less than a degree probably on each side of its initial direction. In consequence, we must postulate very close juxtaposition of the pivoted magnets in the model with but little clearance between the poles. Nevertheless, employing both theoretical calculation and experimental verification, Ewing shows that such a model fails to represent quantitatively the stages of magnetisation ; for it would necessitate an external field sufficiently strong to rupture the arrangement of the atomic magnets, which would be at least a million times as great as the field which actually suffices to carry soft iron beyond the quasi-elastic stage into the state when hysteresis begins to manifest itself. Impressed by these considerations Ewing proposes a new model which while retaining the idea of magnetic control, escapes the excessive stability of the old model and satisfies the essential condition that the Weber element in each atom may turn only through a very small angle before becoming unstable. The idea is that the electrons in each atom comprise two groups, which by reason of rotatory motion in limited orbits or of ring structure, constitute two magnetic systems ; an inner one possessing magnetic moment and capable of turning in an applied field, and an outer which is to be regarded as held approximately fixed relative to neighbouring atoms when the atom is part of a solid body, and therefore takes its proper place in the space-lattice of a crystal. The outer group behave as a set of fixed directing magnets and so the model would be one in which each model atom contained a Weber element (the inner part) capable of turning, controlled, however, not by neighbouring atoms, but by the remaining parts (outer) of its own atom. To illustrate this idea Ewing has constructed models with eight fixed magnets pointing along the diagonals of a cube, their centres being at the corners of the cube, and an inner part (representing the Weber element) which could be either a simple pivoted magnet or an octet of poles set at the corners of a cube (also pivoted at its centre) or a quartet of poles occupying the corners of a regular tetrahedron. The mutual magnetic forces between the Weber element and the outer group determine the range through which the Weber element can turn stably, and when this range is exceeded, it turns irreversibly in a manner involving hysteresis from one position of stability to another. Calculation and experiment combine to show that in this model the strong magnetic forces between the Weber element and *separate portions* of the outer group make the range of stable deflection very narrow and yet are more or less completely balanced, so that the stability is feeble. This structure has obvious points of similarity with the structures dealt with in the last contribution to this section of "Recent Advances," in which electrons are supposed to be confined to narrow limits near the corners of regular polyhedra. In particular the Langmuir hypothesis concerning the arrangement of the 26 planetary electrons in the iron atom is that 2 form an inner "stable pair," and the remaining 24 are at the corners of three concentric cubes with common diagonals—an arrangement which could easily be conceived to possess the two elements postulated in Ewing's new model of ferromagnetic induction.

However, as stated at the outset, the model has been shown by Whittaker to possess the necessary elements to render it a suitable mechanism for "quantum" exchanges of energy between an atom and an electron which encounters it. In his paper Whittaker obtains the equations of motion for a simple "Weber element" consisting of a magnet rotating in a plane round one of its poles as centre, and an electron approaching it from a distance along a line passing through the stationary pole at right angles of the plane of rotation. The approaching electron constitutes an electric current and produces the usual circular magnetic field which will set the magnet (supposed to be at rest initially) in rotation. Now the rotating pole will constitute a "magnetic current" and in its turn produce an electric field whose lines are linked with the circular path of the pole in the same way (*except for a difference in sense*) as the lines of magnetic force are linked with a circular electric current. Furthermore this electric field will oppose the approach of the electron; this can be seen if attention is paid to the bracketed remark concerning sense in the previous sentence; indeed, the whole occurrence is an illustration of the Faraday–Lenz rule. If, therefore, the kinetic energy of the electron is insufficient, it is stopped before reaching the atom, all its energy having been communicated to the rotating magnet. Under the influence of the electric force due to the magnetic current (now at its maximum value) the electron begins to recede, and in so doing creates a magnetic field which gradually brings the rotating magnet to rest; the electron returns to a distance with its old velocity and energy, having experienced what is practically a perfectly elastic encounter with the atom. But if the energy of the electron exceeds a certain critical amount, it is able to pass right past the magnet (that is through the atom) and travel to a great distance on the other side with its energy reduced by this critical amount, which is now retained by the rotating magnet. This is a very striking parallel to the now well-known phenomenon of "single-line" spectra first discovered by Franck and Hertz in 1914, and since amply confirmed by the researches of McClennan, Horton, Goucher and others. In this an atom is caused to emit radiation of frequency $\nu$ by collision with an electron, the amount of kinetic energy of the electron which is absorbed by the atom being $h\,\nu$, ($h$ = Planck's constant): an electron whose kinetic energy before the encounter is less than $h\,\nu$ is incapable of stimulating the atom to emit the radiation and is repelled from the atom without any loss of energy. The manner in which the atom can pick up just a definite amount of energy, neither more nor less, has been suggested above, and Whittaker's equations lead to a value $2e^2m^2/\mathrm{I}$ for the critical energy, where $e$ is the electronic charge, $m$ the pole strength, and I the moment of inertia of the magnet. The mathematics can be applied in a similar manner to any magnetic system which, like a Weber element, can be set in rotation by a magnetic field. The angular velocity retained by the magnet is given by

$$\mathrm{U} = e\,m\,\omega$$

where U is the critical energy.

It constitutes a strong element of support for this explanation of quantum absorption of energy that it postulates no structure in the atom beyond one of a kind which has already been introduced to account for a totally different class of phenomena, those of induced magnetisation.

It remains to be seen how the energy so absorbed in these discrete quantities and resident in the atom as energy of a magnetic current, becomes transformed into the radiant form. At this point Whittaker frankly forsakes the model and simply postulates that a magnetic current can be replaced by an "electric shell," *i.e.* a condenser, just as we look upon a magnetic shell and an electric current as equivalent. Such a condenser discharging is likewise equivalent to the familiar Hertzian oscillator of the text-books whose frequency is given by

$$\nu = 1/2\pi\sqrt{\mathrm{LC}}$$

where L is an inductance and C a capacity. We can assume that the vibrators in different atoms merely differ in scale, but are alike in geometrical pattern, so that L/C is the same for all vibrators. Now it is a fact which is worthy of notice that the quantity

$$e^2\sqrt{L/C}$$

is one whose dimensions are the same in all possible systems of electromagnetic units; its dimensions are in fact those of Action. Since the assumption of similar geometric pattern leads to identical values for L/C for all atoms, one is encouraged to assume that $e^2\sqrt{L/C}$ is a universal constant, and it appears on investigation that the energy first absorbed and now radiated by the discharging oscillator is connected with the frequency $\nu$ above by the equation

$$U = \pi e^2\sqrt{L/C} \cdot \nu$$

which is just Planck's equation if we identify $h$ with $\pi e^2\sqrt{L/C}$.

It appears that Whittaker's rather cavalier manner of treating the model at the end raised some criticism in the discussion which followed his paper; he, nevertheless, defends his attitude in some characteristic remarks which deserve quotation, so important are they to a philosophical view of the development of Physical Science: "At the same time," he says, "we must bear in mind that the function of models is merely to suggest the correct differential equations of the phenomenon: when the differential equations have been obtained the model may be discarded. Instances of this in the history of Physics are abundant: to name only the most famous of them, it was a model of rolling particles, idle wheels, and cellular vortices that suggested to Maxwell the correct differential equations of the ether. The model, having served its purpose, soon dropped out of sight: and the ether itself appears to be following it into oblivion. The differential equations alone remain, and in the hands of the relativists have provided the foundation for a complete reconstruction of our ideas of the universe."

However, it is not impossible to retain the model. Whittaker, himself, in a note added to his paper before publication, points out that if we add a circuit of wire (supposed perfectly conducting) linked once with the rotating magnetic structure we obtain the necessary oscillations in the magnet's motion and the current induced in the wire to set up radiation. But, probably, those interested in models will prefer Ewing's suggestion, in which he pointed out that Whittaker had made use only of the interior, movable part of the new ferromagnetic model. If one does not forget the outer stationary part, it appears that when the critical energy is communicated to the rotating part by the electron which has passed through, the rotation is checked by the outer portion and the rotating system (which can be conceived as a number of " magnetic spokes ") is started back once more and oscillates to and fro like the balance wheel of a watch until its energy is expended in the emitted radiation. But, of course, such oscillations are again only another aspect of the condenser discharging in an oscillatory fashion, and just the same type of mathematical result is obtained.

Other papers, containing the substance of remarks made at the meeting, are contributed by H. S. Allen, R. A. Houstoun, and Professor Peddie.

The success of the model is striking testimony to the view which has gradually been gaining ground that in fundamental explanations of atomic behaviour, we have too often lost sight of the importance of magnetic phenomena and somewhat over-stressed the purely electric side of natural occurrences.

J. R.

**PHYSICAL CHEMISTRY.** By W. E. GARNER, M.Sc., University College, London.

*The Ionisation Theory of Ghosh.*—The immediate successes achieved by the theory of dilute solutions as developed by van t'Hoff, Arrhenius, and Ostwald towards the end of the nineteenth century, raised hopes which have not been fulfilled by subsequent experimental work. The simple postulates of the earlier investigators have not been found adequate for the treatment of solutions of strong electrolytes. Thus the Ostwald dilution law fails completely in the case of these solutions.

During the last two decades, numerous investigators have sought the complete solution of the problem of the relationship between ionisation and conductivity. The effects of viscosity, hydrate formation, complex ion formation, etc., have been studied without throwing much light on the deviations from the simple postulates of Arrhenius. It is not surprising, therefore, that the theory of Ghosh, which rejected the fundamental assumptions of Arrhenius and proposed a new electrical theory of dilute solution, was received with general favour. Nernst, in the new edition of his textbook (*Theoretrische Chemie*, p. 615), Noyes, McInnes, and many other workers have given their support to the new ideas. The theory has, however, been so severely criticised by Partington (*Trans. Faraday Soc.*, 1919, **15**, 111), Chapman and George (*Phil. Mag.*, 1921 [vi], **41**, 799), Kraus (*J.A.C.S.*, 1921, **43**, 2514), Kendall (*J.A.C.S.*, 1922, **44**, 717), and by S. Arrhenius (*Z. Phys. Chem.*, 1922, **100**, 9) that one is faced with the conclusion that this acceptance of the theory was somewhat premature.

The theory of Ghosh is based on the following postulates: (1) complete ionisation of the electrolyte; (2) arrangement of the charged particles in a space-lattice in the solution; (3) the oppositely charged ions can form saturated electrical doublets and the work required to separate them is the electrical work done in separating two charged particles; (4) an ion is free to conduct the current only if its kinetic energy is greater than half the work required to separate it from its partner; and (5) the distribution of velocities is according to the Maxwell law. For binary electrolytes he deduces a relationship for $a$, the degree of ionisation as defined by conductivity measurements,

$$2RT \ln \frac{1}{a} = \frac{N_0 e^2 \sqrt[3]{2 N_0}}{D \sqrt[3]{V}}$$

where $D$ = dielectric constant of the solvent.

Criticism is directed, in the first place, against the choice of experimental data, the methods of calculation, and the narrow range of concentration over which comparisons were made between theory and experiment. Incorrect values were used by Ghosh for $\Lambda_\infty$, the dielectric constant of water, the degrees of polymerisation and ionisation in non-aqueous solvents, etc. When the corrected values are introduced into his equations, relatively large deviations are observable between theory and experiment. Thus Arrhenius shows that in ethyl alcoholic solutions the discrepancy is particularly marked. For $n$ KI the calculated value for $a$ is 31·4, whereas the observed value is 22·4.

In the second place, it is urged that the postulates are inconsistent among themselves, and that the equations which Ghosh employs do not follow from his postulates. It is also doubtful if the Maxwell law of distribution can be applied to a system of charged ions. Kendall shows that the electrical work necessary to disperse $2N$ particles of a dissolved salt will be $A = 1{\cdot}75\ NE^2/Dr$ instead of $NE^2/Dr$ as assumed by Ghosh. Also Chapman and George point out that the expression used for the distribution of velocities is erroneous. When both of these corrections are made, the disagreement between theory and experiment is seen to be far beyond the limits of experimental error.

The theory of Ghosh requires that all electrolytes of the same type should be equally ionised. Partington shows that considerable divergences exist between the experimental values of $\frac{\mu_v}{\mu_\infty}$ for different electrolytes in aqueous solution. The divergences are still more marked in solutions of non-electrolytes. Ghosh gets over this difficulty by a new method of deriving $\Lambda_\infty$, but unfortunately the values obtained are in disagreement with the precision measurements of Washburn and Wieland at high dilutions. Kendall points out that the Ghosh theory fails in all solvents with a low dielectric constant. In such solvents ionisation should proceed exceedingly rapidly with increase in the dilution; even the specific conductivity should increase with the dilution. In practice, however, exactly the opposite behaviour is exhibited.

Kraus shows by graphical methods that the equations of Ghosh can fit the experimental results over only a small range of concentrations. Thus Log $\Lambda$ plotted against the cube root of the concentration should lie on a straight line if Ghosh's theory were applicable, whereas the experimental points lie on a curve concave towards the axis of concentrations at low concentrations and convex towards this axis at high concentrations. Another weakness of the theory is that it ignores the possibility of any specific influence of the solute on the solvent, such as any change in the dielectric constant of the solvent which may have occurred after the solution of the electrolyte. Kendall would go further and ascribe conductance to the solvent. He considers that both the Arrhenius theory and the theory of complete ionisation are at fault in referring conductance in solution entirely to the solute.

These weighty objections do not invalidate the whole of the theory of Ghosh. It would appear, however, that modifications in the original postulates will be necessary if the new line of attack on electrolytic solutions is to prove fruitful.

*The Constitution of Metallic Substances.*—Kraus, in a recent communication (*J.A.C.S.*, 1922, **44**, 1216), has thrown new light on the properties of metallic substances. According to modern views, metals owe their characteristic properties chiefly to the presence of freely moving valence electrons. In the formation of a salt from a metal, these electrons are given up to an electronegative element or group, and the metallic properties disappear. According to Kraus, metallic elements are salts in which the electronegative group is replaced by the negative electron. Support may be gathered for this view from the behaviour of metals when dissolved in liquid ammonia. These solutions have been shown by Kraus (see SCIENCE PROGRESS, 1921, **62**) to exhibit properties intermediate between those of metals and electrolytes. At low concentrations, even the alkali metals lose their metallic properties. Thus a dilute solution of a metal is virtually a solution of a salt giving positive and negative ions resembling those of typical electrolytes. The anion, under these conditions, consists of a negative electron which is rather loosely associated with ammonia molecules. With increase in the concentration of the metal, the conductivity increases enormously and becomes metallic, practically the whole of the current being now carried by the freely moving negative electrons.

The behaviour of solutions of metals in ammonia is similar to that of solutions of salts in water. Thus metallic calcium reacts with potassium chloride in ammonia solution according to the equation, $2KCl + Ca = CaCl_2 + 2K$ and bismuth chloride with sodium thus: $BiCl_3 + 6Na = 3NaCl + Na_3Bi$. These reactions emphasise the salt-like behaviour of metals in ammonia solution.

Compounds of the alkali metals with the heavy metals of the fourth, fifth, and sixth groups are very soluble in ammonia, giving solutions which are characteristically coloured. These solutions behave as if the electropositive element is present as cation, and the more electronegative element as a more or less complex anion. A solution of lead and sodium in liquid ammonia gives a complex anion containing lead and sodium which is deposited on the anode on passing an electric current. Sodium forms several compounds with tellurium which give complex ions in ammonia solution. $Na_2Te$ is insoluble in ammonia, but $Na_2Te_2$ and $Na_2Te_4$ are soluble, giving deep violet and deep red solutions respectively. The anion in these cases appears to be $Te^{--}$ associated with additional tellurium, $Te\ Te^{--}$ and $Te_3\ Te^{--}$. This view of the constitution of the complex tellurium ion is in harmony with the accepted theory of the constitution of the complex sulphide ions, $S.S^{--}$, $S_2S^{--}$, $S_3S^{--}$, $S_4S^{--}$, $S_5S^{--}$. The chemical behaviour of metallic compounds in solution indicates that they are true electrolytes. Thus the lead compound with sodium reacts with a cadmium salt according to the equation, $Na_2Pb_x + Cd(NO_3)_2 = 2NaNO_3 + CdPb_x$, the compound $CdPb_x$ being precipitated. The corresponding $NH_4Pb_x$ is unstable, decomposing into ammonia, hydrogen and metallic lead. An interesting case occurs when the electronegative ion of a metal is precipitated by means of an electropositive ion of the same metal. Thus sodium plumbide on the addition of lead nitrate precipitates lead according to the equation, $Na_4Pb_9 + 2Pb\,(NO_3)_2 = Pb_2Pb_9 + 4NaNO_3$. The precipitated lead may be regarded as lead plumbide. These reactions suggest that the metals themselves occur as compounds in which some of the atoms are charged positively, and some negatively. The formation of such compounds in the solid state would hinder the free movement of the valence electrons and hence diminish the conductivity. The low equivalent conductivity of the less electropositive elements suggests that they are not homogeneous, but contain positively and negatively charged ions, between which some of the valence electrons are tightly bound. This view is supported by the tendency of these metals to form complex anions in ammonia solution.

The large number of compounds derivable from a given pair of metallic elements has been an insurmountable obstacle to the extension of the normal valency conceptions to intermetallic compounds. If, however, it be acknowledged that metals tend to form complexes analogous to those of sulphur, then this difficulty will disappear. The equivalent conductivity of metallic compounds, their heats of formation, and their mechanical properties are in agreement with the hypothesis that these compounds are in effect salts. Their physical properties are intermediate between those of pure metals and salts. Thus metallic compounds are, as a rule, hard and brittle. This resemblance between metallic compounds and salts is the closer the more electropositive one constituent and the more electronegative the other constituent of the metallic compound.

The occurrence in the free state of radicals of the type $C_3H_7Hg$ possessing the properties of metals, throws light on the source of the negative electron to which substances owe their metallic properties. These electrons are evidently the valence electrons.

## ORGANIC CHEMISTRY. By O. L. Brady, D.Sc., F.I.C., University College, London.

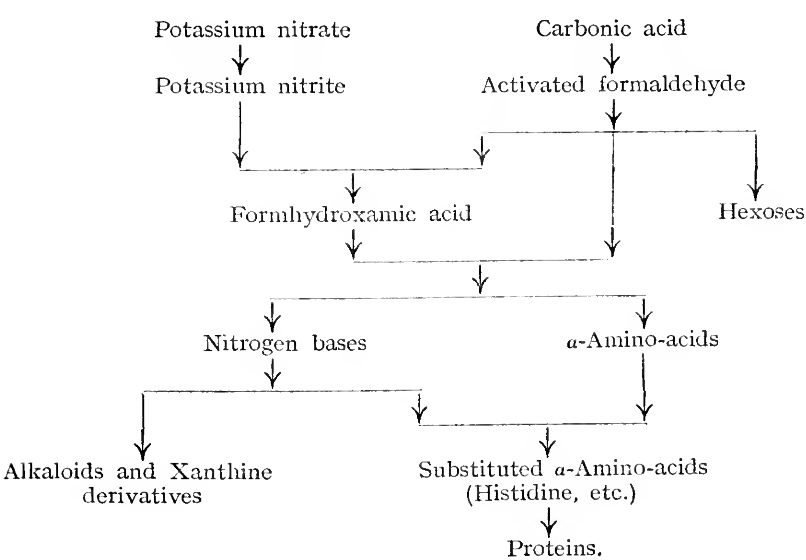
*Photosynthesis of Nitrogen Compounds from Nitrates and Carbon Dioxide.*—In the January number of this journal an account was given of the synthesis *in vitro* of formaldehyde and carbohydrates from carbon dioxide and water under the influence of visible light, thus imitating the first stage in the synthesis of plant products. Baly, Heilbron, and Hudson (*Jour. Chem. Soc.*, 1922, **121**, 1078) have now extended this work to the study of the synthesis, under the influence at present of ultra-violet light only, of complex nitrogenous compounds.

The original source of nitrogen for plant synthesis is either nitrates or ammonia; the present paper deals exclusively with nitrates, but a further communication is promised in which ammonia will be considered as a starting material. The reduction of nitrates to nitrites is known to take place in the plant, and Moore and Webster (*Proc. Roy. Soc.*, 1919, [B], **90**, 158) have shown that the same reaction takes place under the influence of ultra-violet light. Baudisch (*Ber.*, 1911, **44**, 1009) showed that when an aqueous solution of potassium nitrite containing methyl alcohol was exposed to ultra-violet light, formhydroxamic acid was produced ($CH_3OH + KNO_2 \rightarrow$

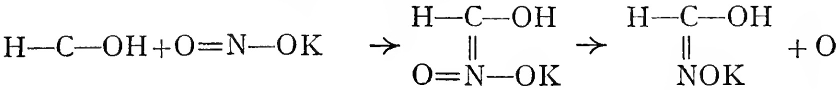
HO . CH : NOK + $H_2O$), and in a series of papers describes a number of experiments in which he obtains evidence of the formation of complex nitrogenous plant products by photosynthesis. For example, by the action of ultra-violet light on potassium nitrite solution in the presence of carbon dioxide with ferric chloride as a catalyst he obtained evidence of the formation of amino-acids, and in solutions of potassium nitrite and formaldehyde exposed to ultra-violet light, of an alkaloidal compound similar to nicotine. Baly, Heilbron, and Hudson, working in a rather more systematic manner, have obtained similar results, and by the assumption of the formation of an active form of formaldehyde containing bivalent carbon have suggested an ingenious mechanism for the synthesis of nitrogenous plant products.

The conception of activated formaldehyde is new to this paper, and the authors consider that, by the action of ultra-violet light, formaldehyde is converted into an active form which, in the absence of other reagents, at once undergoes polymerisation to sugars. They go on to state that this active phase is the same as that which is the first product of the photosynthesis of formaldehyde from carbonic acid, and therefore in the living plant sugars are produced directly without the actual formation of the ordinary non-reactive molecules of formaldehyde. This seems to introduce an unnecessary confusion. In the previous paper Baly, Heilbron, and Barker showed that by absorbing rays of greater wave-length than $290\mu\mu$, which they showed brought about the polymerisation of ordinary formaldehyde to sugars, the aldehyde could be obtained in quantity by the action of ultra-violet light on solutions of carbon dioxide. As under the normal conditions of plant growth the polymerising rays are also present, the failure to detect formaldehyde in leaves is easily explicable, but the very fact that light of a different wave-length is required to activate the formaldehyde so that it at once polymerises to that required for the synthesis of the formaldehyde itself does not suggest that the newly synthesised formaldehyde is an active modification. It would seem that the activated compound is formaldehyde which has been exposed to light of wave-length $290\mu\mu$, and no experimental work in the present paper is at variance with this.

The authors show that formhydroxamic acid is formed by the action of activated formaldehyde on nitrate or nitrite by passing carbon dioxide through aqueous solutions of potassium nitrate or nitrite exposed to ultra-violet light, and also by submitting solutions of potassium nitrite containing formaldehyde to the same influence. Further, formhydroxamic acid itself reacts with activated formaldehyde to give complex nitrogenous products. The reaction with nitrite takes precedence of the polymerisation of the activated formaldehyde to sugars, but when the activated formaldehyde is produced at a rate greater than that at which it can react with the nitrite or with the formhydroxamic acid formed, the excess polymerises to reducing sugars, the two reactions taking place simultaneously and independently. When a solution of formhydroxamic acid containing formaldehyde is exposed to ultra-violet light for twelve hours, the product evaporated with the addition of hydrochloric acid, the residue made alkaline and extracted with ether, nitrogenous bodies are obtained of an alkaloidal nature. Two different substances have been obtained in this way, one a volatile oil and the other a low-melting solid, both of which give crystalline salts with acids and positive tests with all the usual reagents for alkaloids. The alkaline solution on reacidifying, evaporating to dryness, and extracting with alcohol gave a mixture of hydrochlorides of at least one substituted $\alpha$-amino-acid giving the characteristic reaction of these bodies with triketohydrindene hydrate ; the presence of histidine is suspected on account of the colour reaction with diazobenzene-sulphonic acid. The course of phytosynthesis is represented thus :

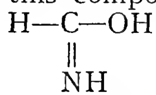



An interesting, if speculative, account is given of the probable course, from the chemical point of view, of the various reactions taking place. The reactivity of activated formaldehyde is regarded as being due to the compound existing in the tautomeric form containing bivalent carbon H—C—OH. This reacts with potassium nitrite

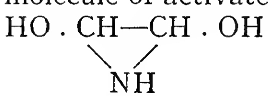


Potassium salt of formhydroxamic acid.

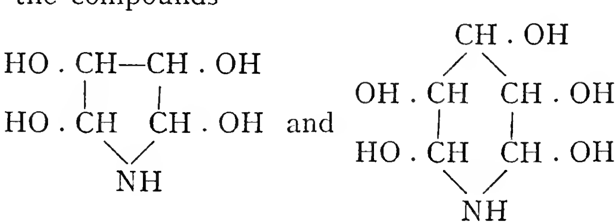
Now in all the reactions between formhydroxamic acid and activated formaldehyde oxygen is liberated, as evidenced by the oxidation of some of the formaldehyde to formic acid, a reaction which does not occur when aqueous solutions of the aldehyde alone are exposed to ultra-violet light. In this connection the presence of an enzyme in leaves which has the power of accelerating the loss of oxygen by various compounds is suggestive. As the oxygen must come from the formhydroxamic acid, this compound at the moment of reaction is represented as



and can then combine with one molecule of activated formaldehyde to form the ring compound

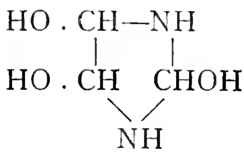


which on rearrangement would give glycine $CH_2NH_2 . COOH$. The methylene group of glycine may react with more activated formaldehyde to give homologues. Such a synthesis postulates that only *a*-amino-acids would be formed, which is invariably the case in phytosynthesis. If the formhydroxamic acid combines with three or four molecules of the aldehyde the compounds

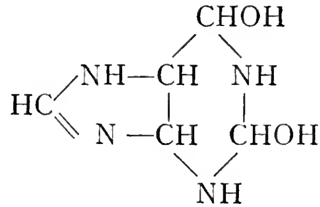


would be formed, which by loss of oxygen and water would give pyrrolidine or pyrrole and piperidine or pyridine compounds respectively. Further combination of pyrrole and pyridine with activated formaldehyde and loss of oxygen and water would give rise to indoles, quinolines, and isoquinolines.

Two molecules of formhydroxamic acid, by condensing with one molecule of the activated aldehyde, would give a compound (i) which by loss of oxygen and water gives glyoxaline, which would condense further with two molecules of formhydroxamic acid to give (ii) a xanthine derivative.



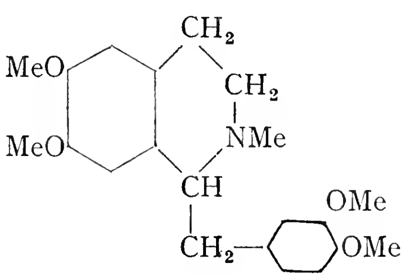
(i)



(ii)

On these lines it seems that all naturally occurring nitrogenous compounds can be built up. Some evidence of the formation of glyoxaline, pyrrole, and pyridine derivatives in the photochemical reaction between formaldehyde and nitrites has been obtained by the authors and other workers, and there is no doubt that the views put forward are very suggestive and open up a large field for further investigation.

*Constitution and Synthesis of Laudanine.*—The constitution of this member of the group of opium alkaloids has been studied by Spath (*Monatsh.*, 1920, **41**, 297, and 1921, **42**, 273). Its relation to laudanosine was confirmed by methylation to racemic laudanosine by means of diazomethane. As the constitution of the latter is represented by (iii) the only problem



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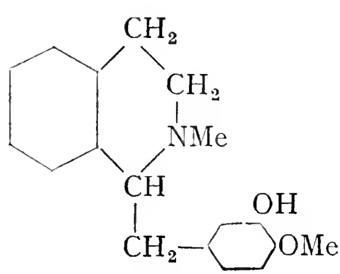
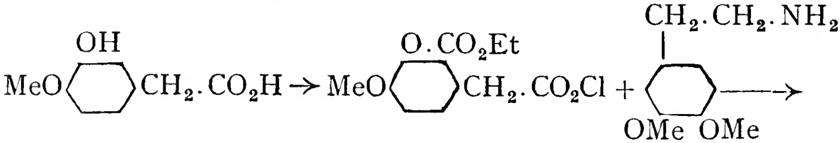


(iv)

which remained was the determination of the position of the unmethylated hydroxyl group. It was known that laudanine on oxidation yielded metahemipinic acid (4 : 5-dimethoxyphthalic acid), so the hydroxyl group must be in the benzyl residue. By ethylation of this group in order to protect and identify it, followed by oxidation of the product, 4-methoxy—3-ethoxy-benzoic acid was obtained; laudanine must therefore have the structure (iv). This has now been confirmed by a direct synthesis. 3-Hydroxy—4-methoxyphenylactic acid (v), prepared by a long synthesis from isovanillin, was converted to its carbethoxy-derivative and then to the acid chloride (vi), which was condensed in benzene solution with β-amino ethyl-3 : 4-dimethoxybenzene (vii). The compound so obtained (viii) was converted into laudanine by ring closure, methylation, reduction, and hydrolysis.

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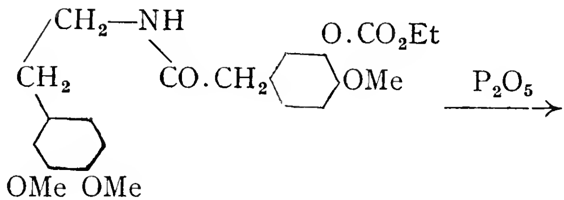
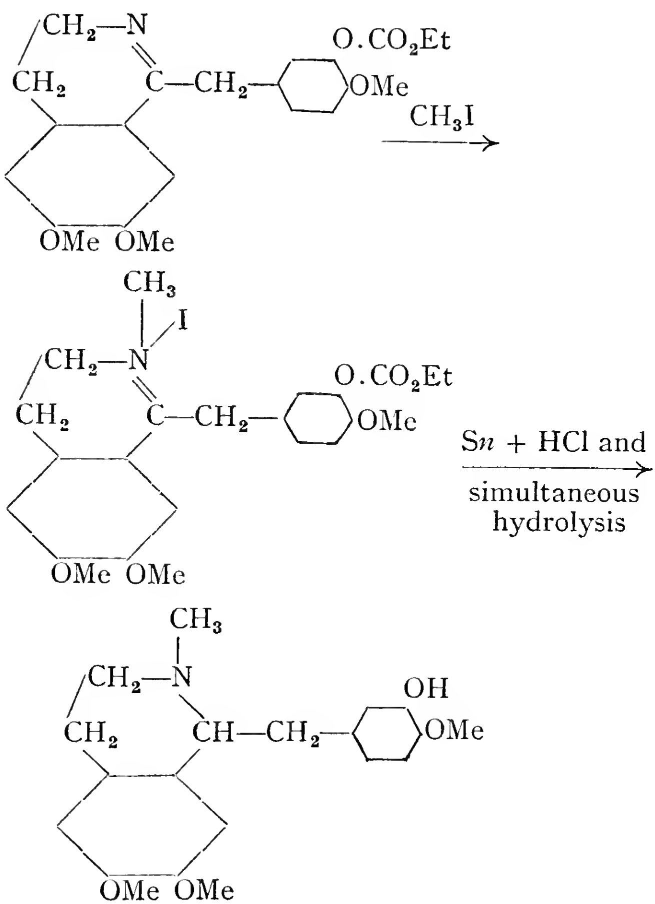
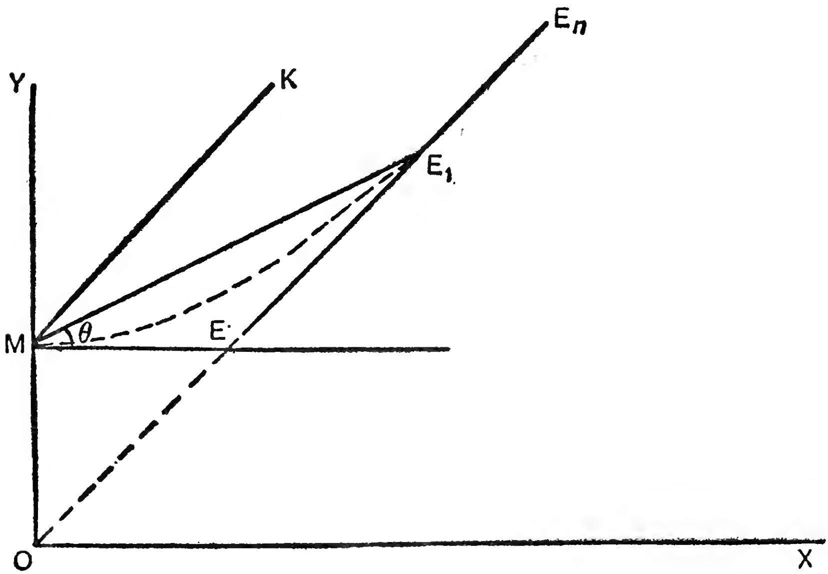



(viii)



**BIOCHEMISTRY.** By Prof. J. C. Drummond, D.Sc., University College, London.

*Biological Value of Proteins.*—The last number of the *Biochemical Journal* (vol. xvi, No. 3) contains an outstanding paper by Martin and Robinson (p. 407) on the minimum nitrogen expenditure of man and the biological value of various proteins for human nutrition. After a useful and concise survey of the historical side of this subject the authors, who state that they commenced the investigation light-heartedly with the object of re-determining the relative values of certain cereal proteins in human nutrition, point out the many difficulties which they encountered in arriving at values which could justifiably be compared. To determine the nitrogen




minimum it is necessary to make a number of experiments each extending over several days, for if reliance is placed on the methods of Thomas (*Arch. Physiol.*, 1909, 219), who calculates the minimum requirements from a very limited number of observations, it is necessary to assume that the value of any protein for biological purposes remains uniform whatever the amount taken. Such an assumption is apparently one for which there is no justification. Thus the biological value of gelatin, if calculated by any of Thomas's formulæ, would therefore appear quite appreciable when the intake was small, but almost zero if the intake was very large. Yet Boruttau (*Biochem. Zeit.*, 1919, **94**, 194) has actually made use of these formulæ to calculate the biological value of gelatin as being 58·2 per cent. The authors make these points clearer by a useful diagram, reproduced below, in which the abscissæ represent real nitrogen intake and ordinates real nitrogen output. Let OM ( $= m$) represent the nitrogen output on a nitrogen-free diet of adequate calorific value, that is, the nitrogen minimum.

If an ideal protein (biological value = 100) is given in gradually increasing amounts and is fully utilised, the nitrogen excretion will be constant at $m$ until the intake rises higher than that value. The point E where ME = OM will therefore represent the point of nitrogen equilibrium, beyond which the graph will follow the line E $E_n$ at an angle of 45° to the axis for increasing intake.

In the case of proteins of value less than 100, equilibrium will not be attained on an intake equal to $m$, but at some higher level represented by $E_1$. On all amounts less than this the output will exceed the intake and the graph will follow the line $ME_1$. Whether this line is straight or curved will depend on :

(1) Indivisibility of the N requirements of the body.

(2) Uniform economy with varying N intake.

If these conditions hold ME will be straight and its equation will be

$$y = m + x \tan \theta$$

where $y$ is the real output corresponding with any real intake $x$ less than $e_1$. Thomas's formulæ can be very simply expressed in terms of $\theta$; Formula B

$$\text{BV} = 100 \, \frac{\text{Urine N in N-free diet} + \text{fæces N} + \text{balance}}{\text{N intake}}$$

becomes
$$100 \, \frac{m + (x - y)}{x} = 100 \, (1 - \tan \theta)$$

If the two above conditions do not obtain, the graph would tend to be a curved line and the curvature would express the fact that a certain fraction of the body's needs could be satisfied by a smaller amount of this protein than would correspond with the amount required to obtain equilibrium. Turning to the actual experiments, in which the authors were themselves the experimental subjects, we find them planned and carried through with remarkable care and precision. The paper should be read in its entirety by all interested in nutrition, but a brief reference to the chief conclusions may be made here. The minimum nitrogen expenditure by the urine was found to be somewhat less than 0·038 to 0·035 gm. per kilo.

On taking a diet of carbohydrate and fat of adequate fuel value the urinary nitrogen falls in a regular and orderly manner, capable of simple mathematical expression, approaching a minimum in five to seven days, and on resuming an ordinary nitrogenous diet the reciprocal phenomenon occurs. Bearing in mind the considerable experimental errors, the ratio $\frac{\text{body N saved}}{\text{food N absorbed}}$ appears to remain constant, whatever amount of nitrogen is taken in the form of whole wheat bread, until equilibrium is reached. In the case of milk the experimental errors are proportionately greater and the ratio may be constant, but with gelatin it is certainly not so ; there being no indication that the amount of body nitrogen saved increases beyond that effected by the smallest quantity of gelatin fed. On these grounds the authors conclude that Thomas's procedure for determining the biological values is justified in the case of bread, doubtful with milk, and impossible with gelatin. It is therefore necessary to determine the ratio $\frac{\text{body N saved}}{\text{food N absorbed}}$ at a point close to but below that of equilibrium before Thomas's method can be regarded as justifiable. The experiments on the authors tended to show that the biological value of the proteins of the whole wheat grain is 31–35 per cent. and that of cow's milk 51 per cent.

*Yeast Enzymes.*—F. Hayduck and H. Haehn (*Biochem. Zeit.*, 1922, **128**, 568) have found that the distribution of zymase in bottom beer yeast and in distillery yeast is different. The former contains free zymase and also zymase in some protoplasmic combination which prevents it showing activity after treatment by Lebedev's process or with acetone. Distillery yeast, which gives no active press juice or active zymase after acetone fixation, contains only combined zymase. Experiments on a torula yeast poor in zymase showed that cultivation in a wort with a poor air supply caused an increased content of zymase and parallel with this an increased nuclei acid metabolism. Willstätter and Racke (*Annalen*, 1922, **427**, 111–41) have investigated the nature of the enzymatic process by which invertase is set free from the yeast cell and the condition in which invertase exists in the cell. The conclusion is that invertase occurs as such, but that it is protected and prevented from diffusing by the membranes of the cell-structure. The function of the liberating enzyme is to destroy these membranes. The liberating enzyme is somewhat unstable, and experiments tend to show that it is of the type of a polysaccharase rather than a proteolytic enzyme.

*Sulphur in Protein.*—This interesting and curiously little explored field of research has provided the subject of a paper by Hoffman and Gortner (*J. Amer. Chem. Soc.*, 1922, **44**, 341). Pure cystine appears to be only slowly destroyed on boiling with 20 per cent. hydrochloric acid, and probably there would not be any appreciable decomposition of this amino-acid during protein hydrolysis by this means. After 192 hours' boiling, over 90 per cent. of the sulphur remainder in the unchanged form, traces of sulphuretted hydrogen and free sulphur being formed from the fraction decomposed. Intramolecular changes appeared to have occurred in the cystine, however, for its precipitability by phosphotungstic acid and its optical rotation both became less. From the residual hydrolysate an isomeric cystine was isolated which crystallised in small microscopic prisms and showed different physical and chemical properties. It was optically inactive. A number of derivatives of the two forms of cystine were prepared, and in every case those prepared from the isomeric form differed from those prepared from the natural "plate" cystine. The authors suggest that the isomeric form is identical with the synthetic cystine prepared by Fischer and Raske and by Erlenmeyer and Stoop, and that "plate" cystine obtained from protein hydrolysis has never been synthesised.

**GEOLOGY.** By G. W. Tyrrell, F.G.S., A.R.C.S., University, Glasgow.

*Orogeny and Highland Tectonics.*—A highly significant view of orogenic processes is developed by R. T. Chamberlin in a paper on "The Building of the Colorado Rockies" (*Journ. Geol.*, **27**, 1919, 145–64, 225–51), wherein he compares and contrasts a *thick-shelled* mountain range such as the Colorado Rockies with a *thin-shelled* range of the type of the Pennsylvanian Appalachians. Thick-shelled mountains are characterised by open gentle folding, moderate crustal shortening affecting a relatively deep zone, and by strong uplift with vertical movement and normal faulting. In thin-shelled mountains a relatively thin superficial portion of the crust has been affected by intense deformation, leading to great overthrusting especially in the marginal parts of the ranges. Horizontal movement is dominant in this type.

The building of the deep-rooted Colorado mountains was accompanied by the extrusion of great masses of lava, whilst this feature was not at all prominent in the Appalachians. Even in different parts of the Rocky Mountains analogous differences appear. In Colorado, where the deformed zone is deep and there has been a large vertical movement, lava flows have occurred in abundance; in the Canadian Rockies, however, where the deformed zone was much shallower, and suffered intense horizontal thrust, but little volcanic activity took place.

In a supplementary paper (*Journ. Geol.*, **29**, 1921, 166–72), Chamberlin extends the comparison of thick-shelled and thin-shelled mountains in regard to intrusive activity also. Little or no intrusion takes place in the marginal overthrust portions of a thin-shelled range, but granitic masses are characteristic features of the cores of the deformed belts. Plutonic masses are also common in thick-shelled mountains. It might perhaps be added that plutonic masses in thin-shelled mountains tend to be foliated, having been intruded concomitantly with the folding; whereas in thick-shelled mountains the batholiths generally have cross-cutting relations and ordinary granitic textures.

These generalisations can be advantageously extended to many other present and past mountain ranges all over the earth. Quite similar views have been developed by Dr. J. A. Douglas in his recent work on the Andes of Peru and Bolivia (*Quart. Journ. Geol. Soc.*, **76**, pt. 1, 1920, 1–61; **77**, pt. 3, 1921, 246–84). He shows that in the Peruvian Cordilleras great zones of overthrusting are entirely wanting, and inverted folds are the exception rather than the rule. He notes the complete dissimilarity of these Andean structures to those of the Alps, a typical thin-shelled range. His observations lead to the view that the folded chains of the Andes are the results of intermittent compression of a series of transgressive deposits laid down in a geosyncline between two ancient resistant masses, represented on the east by the metamorphic and plutonic rocks of the Amazon region, and on the west by the crystalline rocks of the coastal Cordillera. "In the Alpine type of folding vertical uplift has been overshadowed by movement in a horizontal direction, whereas in the Andean Cordilleras the reverse is the case, and the terms 'backland' and 'foreland,' as applied to the direction of movement, have no longer the same significance."

In W. Penck's elaborate monograph on the Argentinian Andes ("Der Südrand der Puna de Atacama, N.W. Argentinien, Ein Beitrag zur Kenntnis des Andinen Gebirgstypus und zu der Frage der Gebirgsbildung." *Abh. Sächs. Akad. Wiss., Math.-Nat. Kl.*, **37**, 1920, 420 pp.) the descriptions and the profile sections corroborate the views expressed by Chamberlin and Douglas as to Cordilleran tectonics. In the region described open folding and enormous igneous action, both intrusive and extrusive, is the rule, although close folding and overthrusting do occur in small, strictly localised areas on the eastern side of the main range. Penck traces the origin of the crustal movements to the entry of magmas beneath the mountain blocks. Minor folding in the upbowed regions is due to secondary intrusion in the strained portions of the crust.

H. Gerth has published a very useful elucidatory and critical summary of Penck's work (*Geol. Rundschau.*, **12**, 1922, 320–40). He, however, does not believe that the orogeny in general and the major folding is due to magmatic movement. The latter may give rise to large-scale epeirogenic uplift or depression, as in the formation of the Mesozoic sedimentation area, the eastern subsidence at the beginning of the Andean movements, and probably also the vertical uplift of the whole mountain system in quite recent times. The secondary magmatic foci and the enormous lava eruptions may have originated from these batholiths, but they play a passive, not an active, rôle in the folding.

In a paper entitled " Die Mediterranen Kettengebirge in Ihrer Beziehung zum Gleichgewichts-Zustand der Erdrinde " (*Abh. Sächs. Akad. Wiss., Math.-Nat., Kl.*, **38**, 1921, 61 pp.) F. Kossmat elaborately discusses the relation between the gravity anomalies and the tectonics of the Mediterranean fold ranges. The main ranges show zones of gravity-defect, as do also the subsided forelands on the outer (N. and N.W.) sides of the Alpine-Carpathian region. The folded chains are not compensated by themselves alone, but in connection with the neighbouring forelands, which are parts of the ranges pressed down by the folding. The interior inbreaks of the Tyrrhenian and Pannonian types are quite different from the forelands, being regions of gravity-excess. The forms of the ranges, the homologies in the courses of the older Eurasian folds, and the arrangement of the major fracture system of the Indo-Gangetic block, show that the fold region is pinched in between stiffer blocks of the earth's crust. The production of differences in regional density distribution is ascribed to tangential movements, due to certain rotational and mass actions in which contraction and crustal enlargement by magmatic action appear in competition. Kossmat believes that the obvious connection of the older and newer Eurasian folds is opposed to Wegener's theory of lateral continental drift.

Prof. W. H. Hobbs' new book on *Earth Evolution and its Facial Expression* (New York: The Macmillan Co., 1921, 178 pp.), which will be reviewed in a subsequent number, should be noted in connection with the subject of orogeny.

A most important paper by G. Frödin on " The Analogies between the Scottish and Scandinavian Portions of the Caledonian Mountain Range " (*Bull. Geol. Inst. Upsala*, **18**, 1922, 199–238) institutes a comparison between the composition, structure, and age of the Seve (Åre) and Köli Schists of Central Scandinavia, and the Moine and Dalradian of the Scottish Highlands. Törnebohm's original view that the Seve Schists and their folding are Pre-Cambrian is now shown to be untenable. The Seve and Köli Schists are now regarded as structural and petrographic facies of Cambro-Silurian rocks, a view supported by continuity with fossiliferous rocks in the adjacent parts of Norway. The folding and metamorphism were accomplished during the long Caledonian orogeny which is held to have begun in late Ordovician times.

These views are applied to the similar Moine and Dalradian groups of the Scottish Highlands. Both these formations are regarded as complexes of rocks of different ages, the Moine being composed mainly of Torridonian, Cambrian, and Lewisian inliers welded together by extreme metamorphism, the Dalradian mainly of Cambro-Silurian sediments. In support of the latter contention, an impressive petrographical and stratigraphical comparison is drawn between the Dalradian and the Ordovician-Silurian rocks of the Southern Uplands. The analogies between the Scottish region and that of Central Scandinavia are thoroughly exploited in aid of the view that the Scottish schist groups, like the Scandinavian, are not of Pre-Cambrian age, and have suffered but one period of folding and metamorphism, namely the Caledonian.

Structural conditions are also similar. Fan anticlines are pressed up in the central portions of synclinal depressions consisting of Cambro-Silurian strata pinched in hollows of the Archæan basement, and squeezed out laterally with the formation of inwardly-dipping recumbent folds and thrusts.

Another important point brought out in this paper is the scepticism of present-day Scandinavian geologists as to the enormous distances (80 to 100 miles, according to Törnebohm) over which the thrust blocks are alleged to have moved. Frödin reduces the thrust distance in Jemtland to one-tenth of the original figures, thus bringing the Scandinavian thrusts to the same order of size as the Scottish. The details of Frödin's work on Central Scandinavian highland geology, referred to above, are contained in a long and important paper entitled "Über die Geologie der Zentralschwedischen Hochgebirge" (*Bull. Geol. Inst. Upsala*, **18**, 1922, 57–197).

The Scandinavian "mountain-problem" is treated by O. Holtedahl (*Quart. Journ. Geol. Soc.*, **76**, pt. 4, 1920, 1–25) for North and South Norway on much the same lines as Frödin for Central Sweden. Few Norwegian investigators, apparently, have ever believed in the pre-Cambrian age of the thrust blocks that overlie rocks of Lower Cambrian age in that country. Materials of different ages make up the thrust blocks, the differences depending on the inclinations of the thrust planes and the depths to which they have reached. Only rarely has their material been brought up from below the pre-Cambrian peneplane surface. Holtedahl gives some illuminating serial sections, showing the progress of events in the Caledonian folding in Finmarken (N. Norway) and the Randsfjord region (S. Norway).

In two recent papers ("Nya Data till Kännedomen om Seve- och Kölibergarternas Kemiska Karaktär," *Geol. Fören. Stockholm Förh.*, **41**, 1919, 369–82, and "Fjällens Kristallina Skiffrar och deras Tolkning," *ibid.*, **43**, 1921, 177–87) P. D. Quesnel maintains somewhat similar views to Frödin's and Holtedahl's in regard to analogous rocks and structures of districts in Northern Sweden.

Coincident with the extensive reinterpretation of the Scandinavian highland problem by the group of investigators referred to above, in which the importance of thrust action is somewhat minimised, Mr. E. B. Bailey propounds an interpretation of the south-western part of the Grampian Highands in which thrusting and "nappes" play a predominating part (*Quart. Journ. Geol. Soc.*, **78**, pt. 2, 1922, 82–131). He believes that the Dalradian Schists there belong to three main structural divisions, which, in descending order, are the Loch Awe nappe, the Iltay nappe, and the Ballappel nappe. The second title is a compound of Islay and Loch Tay; the third of Ballachulish, Appin, and Eilde. Each of these divisions has its own particular stratigraphical facies, but certain correlations from one to another are suggested. The emplacement of these nappes is considered, from various lines of evidence, to have been due to movement from north-west to south-west. Great recumbent folds are a feature of Mr. Bailey's structural interpretations, and the elucidation of these has been greatly helped by the presence of secondary folding, which has bent over the primary folds into such features as the Cowal Anticline, Loch Awe Syncline, Islay Anticline, etc. The work is difficult to summarise, and even to understand by those unfamiliar with at least some of the field evidence; but it is noteworthy that a group of Mr. Bailey's colleagues, along with Prof. Collet of Geneva, have published a note expressing agreement with a large number of Mr. Bailey's fundamental ideas (*Geol. Mag.*, **59**, 1922, 301–3).

**BOTANY.** By E. J. Salisbury, D.Sc., F.L.S., University College, London.

*Variation.*—To the *Journal of Genetics* (vol. xii, pp. 47–89) Prof. Vavilov contributes an important paper under the title of the "Law of Homologous Series in Variation." The author begins by emphasising the immense variety of Jordanean species comprised in the Linnean aggregates, amounting to about 3,000 for *Triticum vulgare*, between 600 and 700 for Barley, and apparently, from the limited cases investigated (*e.g. Trifolium pratense*), these segregrates are no less numerous in wild species. Such polymorphism, which is independent of the innumerable genotypes, calls for systematisation, which the author in this paper suggests might be based on the parallelism in variation to which Eimer and others have previously directed attention.

The strikingly parallel series of varieties in the different species of Wheat; in *Hordeum vulgare* and *H. distichum*; in *Agropyrum repens* and *A. cristatum*, of which fourteen out of fifteen known variants are found in both species; *Cucurbita pepo* and *C. maxima*; are all instanced as cases where related species have been shown to produce exactly parallel series of variants.

Similarly in distinct genera, *Secale* and *Triticum* exhibit no less than thirty-four varietal types of a parallel character. Indeed, the discovery of eligulate types of Wheat actually led to their being sought and found in the Rye. Very striking illustrations are afforded by *Ervum lens*, *Vicia sativa*, *Pisum sativum*, and *Lathyrus sativus*. All these exhibit parallel variations with respect to colour of flowers, shape and colour of seeds, height, period of development, etc.

Parallelism in distinct families is illustrated by the widespread occurrence of albinism, gigantism, nanism, fasciation; root types in Chenopodiaceæ (Beta), Cruciferæ (Brassica), and Umbelliferæ (Daucus); peloria in zygomorphic flowers, etc.

Mimicry is held to be a result of selection of these parallel variations, of which a striking case is afforded by *Ervum lens* and *Vicia sativa*. Here the methods of cleaning by screening and hand picking have resulted in the selection of seed types of the latter which are indistinguishable—alike in form, size, and colour—from those of the former.

Thus the variations of species and genera are held to be members of a definite series comparable to those of the chemist: " Knowing a succession of varieties in one genus or Linneon, one can forecast the existence of similar forms and even similar genotypical differences in other genera and Linneons." Once this fundamental principle is established, then the simplification of nomenclature on this basis need be merely a matter of time.

A genetical study of variegated plants of *Chlorophytum* has been carried out by Collins (*Journal of Genetics*, vol. xii, pp. 1–17) working with the wholly green *C. elatum* and its two variegated forms with a white margin and white middle to the leaves respectively. The seedlings produced by selfing the variety with a white margin are wholly green, as also are those of the type form. Selfing the variety with a white middle region resulted in the production of seedlings all of which were albino. The corresponding form of *C. comosum* selfed gave sixty-six albinos, two variegated and one green.

Various crosses yielded a small proportion of variegated seedlings, but these all showed variegations of an *irregular* character. The crowns formed later by these seedlings, however, exhibit a somatic segregation which may result in the reappearance of the regular type of variegation. Moreover, all four types—viz. green, white margin, white middle, irregularly striped—may be exhibited by the different crowns produced from a single variegated seedling.

Several leaf-colour types have been recognised in the maize. In addition to normal green and pure albino there is a type in which the seedlings are at first albino, and become green as they develop, another variety in which the colour is a uniform yellowish-green, and the striped variety. These have been studied from the cytological standpoint by Randolph (*Bot. Gaz.*, vol. lxviii, pp. 337–75). It appears that the protoplastids from which the chloroplasts arise are all of one type, and the green and colourless plastids respectively are to be regarded as the extremes of a series in which all intermediate conditions are presented. The apparently sharp line of demarcation between the yellow and green regions of the striped variety presents in reality plastids of varying sizes and depths of colour even within the same cell.

The variability of leaf form in *Taraxacum* is a familiar feature to all field botanists, and Sears, who (*Bot. Gaz.*, vol. xxiii, pp. 425–41) has grown numerous plants under varying conditions, finds that dissection of the leaves increases with the age of the plant, and often the degree of hairiness also. This change is exhibited in both moist and dry conditions, but multicipital branching brings about rejuvenescence with a recurrence of the sequence.

Tammes (*Jour. Genetics*, vol. xii, pp. 19–46) has studied the genetical composition of *Linum usitatissimum* with respect to colour. Six factors determine the colour of the flowers, and of these two, which must both be present, are essential whilst the rest are intensification factors. Two of these, with an additional factor, determine the blue colour of the anthers, whilst still another determines the brown colour of the seed coat. The eight factors thus concerned with colour are all present in the common blue Flax, and all the other types studied were found to be of the nature of loss mutants.

A remarkable *Narcissus* growing wild and perhaps a mutant of *N. angustifolius* has been found in the Vaudese Alps by D. Rieser (*Bull. Soc. Vaud. Soc. Nat.*, **53**, pp. 341–2). The outer three perianth segments are broad and trilobed, whilst the three inner are laciniate at the base with a long and narrow median segment. Of the six stamens the three inserted at the mouth of the yellow corona are sterile.

*Ecology.*—Working with a fertile calcareous soil rich in plant food and having a maximum water capacity of 45 per cent., Greaves and Carter have determined the effect of variations in the soil moisture and salt content on bacterial activity. The greatest ammonifying power was exhibited at a water content of 30 per cent., and in the presence of carbonates this value remained, but when magnesium sulphate was present the optimum condition was 25 per cent. The maximum nitrifying power was exhibited at a water content of 20–30 per cent., the value varying with the nature of the salts present. It is important to note that the relative toxicity of various salts to nitrifying organisms decreased as the amount of water added increased (*Soil Science*, vol. xiii, pp. 251–70).

The effect of tree products on Ammonification and Nitrification has been studied by Gibbs and Werkman (*Soil Science*, vol. xiii, pp. 303–22). It was found that Fir needles depressed the ammonification by about 25 per cent., but Larch needles and Bracken litter caused very slight depression.

Nitrification of ammonium sulphate was depressed by all types of litter, even 3 per cent. of Bracken litter causing a diminution of over 25 per cent., whilst the needles of *Abies grandis*, *Pinus ponderosa*, and *Thuja plicata* almost totally inhibited the process.

A summary of the results of experiments on the viability of buried seeds, initiated by Dr. Beal in 1879, is furnished by Darlington (*Am. Journ. Bot.*, vol. ix, p. 268). The seeds were placed in uncorked bottles and buried with the opening directed downwards. Twenty samples each of fifty seeds were buried, and this was done for twenty-three species ; mostly common weeds. After forty years *Brassica nigra* and *Rumex crispus* exhibited a percentage germination of 18 and *Plantago major* 10 per cent. *Amaranthus græcizans* yielded no less than 66 per cent., and *Œnothera biennis* 38 per cent. Other species which had survived were *Amaranthus retroflexus*, *Ambrosia elatior*, *Lepidium virginicum*, *Portulaca oleracea*, and *Chenopodium album*. *Capsella bursa-pastoris* germinated after thirty-five years, but failed to do so after forty years. Since, however, such a failure with this species occurred also after ten years, the recent result may have little significance.

*Taxonomy*.—A new genus of Umbelliferæ allied to *Hydrocotyle* is described by Norman under the name of *Cotylonia* (*Jour. Bot.*, vol. ix, p. 166). Dr. Schonland (*Ann. Bolus. Herb.*, Dec. 1921) has described a new genus of Crassulaceæ to include a single species, *Pagella archeri*. Its outstanding features are the markedly syncarpous ovary associated with a haplostemonous tetramerous flower and the presence of two separate placentas in each loculus. The largest plants are about 20 mm. in diameter.

A new species of the interesting genus *Brachiomonas* under the name *B. simplex* is described by Hazen (*Bull. Torrey. Bot. Club*, **49**, pp. 75–92) from material collected in Norway, and at Cullercoats and Plymouth in this country. In the following number of the same journal (pp. 123–40) Hazen describes two new species of *Lobomonas*, of which one was collected in Surrey.

Vol. xlvi, No. 305, of the *Jour. Linn. Soc. Bot.* is devoted to an account of Berkshire Heleoplankton by Griffiths, and to a description of the Cryptogamic vegetation of New Caledonia. The latter includes descriptions of new species of Hepaticæ by Pearson, a new genus of Stigonemaceæ by Miss Carter, a new *Nitella* by Groves, new genera and species of Lichens by Miss Lorrain Smith, and new Fungi by Miss Wakefield. New genera of Mosses are described by Dixon (*Jour. Bot.*, vol. lx, p. 101) of which four are placed in the Funariaceæ and one in the Hookeriaceæ.

As a supplement to the latter journal, Dr. Watson contributes a key for the determination of Lichens in the field.

*General.*—To the current number of Messrs. Charlesworth & Co.'s Catalogue, Mr. Ramsbottom contributes an excellent summary of the literature on Orchid Mycorrhiza, and incidentally of the general problem. Attention is called to the antiquity of this type of association found even in the Devonian plants, and the suggestion is made that perhaps ectotrophic and endotrophic mycorrhiza represent respectively the conditions of fungus parasitic on the phanerogam and *vice versa*. A very clear account is furnished of the germination process in orchids, and in this connection a tribute is paid to the work of the late Mr. J. Charlesworth.

Under the title of "Developmental Selection" Bucholz calls attention to the frequency of competition between—ovules within the same ovary, twin embryos, pollen tubes (gametophytic selection), male or female gametes. Evidence is brought forward to show that polyembryony is by no means uncommon in Ferns, Gymnosperms and Angiosperms, which may well indicate a widespread gametic selection. Pleurality of embryos has also been shown to occur in the gametophytes of Lycopodiales and Equisetales. Such developmental competition is calculated to bring about the survival of the gametes and embryos most fitted for the uniform environment of the parent, and thus extends the concept of natural selection to the earliest phases of development (*Amer. Jour. Bot.*).

**PLANT PHYSIOLOGY.** By Prof. WALTER STILES, M.A., Sc.D., University College, Reading (Plant Physiology Committee).

*Flower and Fruit Formation.*—While the physiology of the vegetative body of the plant has received very great attention from every conceivable aspect during the last century, the physiology of reproduction has received only slight attention, although from the economic point of view this may be relatively of considerably greater importance. During the last few years this discrepancy between the amount of work devoted to the vegetative body and the reproductive organs from the physiological point of view has to some extent disappeared, and it is not surprising that the greater proportion of the work dealing with fruit formation should have been done in institutions devoted to investigations in agriculture and horticulture having an economic significance.

That the composition of the soil has an important influence on the production of fruit was noted and commented on by many earlier observers, including Charles Darwin, who devoted some attention to this question in his *Variation of Animals and Plants under Domestication.* Further observations on this question have been recorded recently. Thus J. Farrell (*Journ. Agric. Victoria,* **15**, 142, 1917) found that the Jonathan apple is usually more or less self-sterile on soils in Victoria rich in nutrient substances, while on poor soils it becomes self-fruitful. The reverse phenomenon seems to be the case with an American grape ("Hope"), which only produces hermaphrodite flowers when carefully cultivated, the gynæcium becoming functionless if the culture is poor.

How far particular nutrient substances in the soil influence the formation of flower buds and the subsequent production of fruit is in considerable doubt. Some evidence appears to be accumulating to the effect that the addition to the soil of fertilisers containing nitrogen, such as sodium nitrate, increases not only the number of flowering short shoots ("spurs") in apples, but also the percentage of flowers which produce fruit (C. C. Wiggans, "Some Factors Favouring or Opposing Fruitfulness in Apples," *Missouri Agric. Sta. Res. Bull.,* **32**, 60 pp., 1918), and a high nitrogen content in the spur itself certainly appears to further the production of fruit from the flowers (E. M. Harvey and A. E. Murneek, *Oregon Agric. Exper. Sta. Bull.,* **176**, 1921).

There can be no doubt whatever of the influence of climate on the production of flowers and fruit, although it may not always be easy to determine which factors of the environment are those particularly responsible for any observed effect. M. J. Dorsey ("Relation of Weather to Fruitfulness in the Plum," *Journ. Agric. Res.,* **17**, 103–26, 1919) found that low temperature and excessive rain are the climatic factors which influence most unfavourably the setting of fruit in the plum. Low temperature brings about retardation of growth of the pollen tubes, the time required for the pollen grain to germinate and the tube to grow through the tissues of the style to the ovule varying from 4 to 12 days according to the temperature, while if the temperature should fall below zero, growth would no doubt be inhibited altogether. It is thus possible during a period of cool weather for development of the pollen tube to take so long that fertilisation cannot be effected, as the style decays and falls off in 8 to 12 days after flowering. Temperature may also have an indirect effect in limiting the movements of the pollination agencies, as bees, for example, do not generally leave the hive until the temperature reaches about 15° C., and are stated not to fly at a temperature below about 5° C.

Rain acts on the production of fruit by closing the anthers or preventing them from opening, so that dissemination of pollen is prevented. If pollination is once effected rain has little power to wash the pollen from the stigma, and even if it should be so washed away, the stigmas will secrete their viscous fluid a second time.

Too low rainfall or other climatic influences tending towards a condition of drought may also influence unfavourably the production of fruit. Thus high temperature with consequent high rate of transpiration, low atmospheric humidity and low rainfall with consequent low water content of the soil, and high winds also tending to a high rate of transpiration, are all factors which may so disturb the water relations of the plant that an abscission layer forms in the flower stalk so that the flower or fruit is cut off and shed immaturely. (Cf. H. Molisch, "Pflanzenphysiologie als Theorie der Gärtnerei," Dritte Auflage, 1920.) That this is the probable cause of premature shedding of fruit in the Washington navel orange has been shown to be the case by J. E. Coit and R. W. Hodgson (*California Agric. Exper. Sta. Bull.*, **290**, 1918), and in cotton by F. E. Lloyd, "The Abscission of Flower Buds and Fruits in Gossypium, and its Relation to Environmental Changes" (*Trans. Roy. Soc. Canada*, Ser. 3, **10**, 55–61, 1916).

Very interesting observations on the influence of illumination on flowering and fruiting have been made by W. W. Garner and H. A. Allard ("Effect of Relative Length of Day and Night on Growth and Reproduction of Plants," *Journ. Agric. Res.*, **18**, 553–605, 1920; "Flowering and Fruiting of Plants as Controlled by the Length of Day," *Yearbook U.S. Dept. Agric.*, 377–400, 1920) by placing potted plants in dark chambers during some of the hours of daylight and so shortening the period of illumination, and by lengthening the daily period of illumination by the use of artificial light at night. These workers found that the flowering and fruiting stages in a number of species are only reached if the length of the period of illumination falls within certain limits. Under ordinary climatic conditions flowering and fruiting therefore occur at a definite period of the year, but if the daily illumination is artificially reduced, the time for flowering and fruiting to take place is also reduced, while if the daily period of illumination is lengthened, the flowering and fruiting stage is reached correspondingly later. The authors thus regard it as possible by artificial means to produce flowers and fruit at any season of the year. The results with tobacco may be cited as examples. With daily light periods of 12 hours the plant required 152 to 162 days to flower, with illumination for 7 hours only in every day the period was reduced to 55 to 61 days. How far these results can be applied to all species of plants remains to be seen.

Wind is a side factor of some importance in regard to fruit production. It may act directly by damaging the flowers and by causing the evaporation of the stigmatic fluid excretion so that pollen does not adhere to the stigma, or it may act indirectly by interfering with the work of pollinating insects. M. J. Dorsey (*Journ. Agric. Res.*, **17**, 103–126, 1919) states that the unfavourable action of wind is generally more pronounced in the early stages of the flower than in the later.

In horticultural practice it is an important question whether spraying with arsenical, copper, and other sprays has any effect on fruit production. While W. L. Howard and W. T. Horne (*California Agric. Exper. Sta. Bull.*, **326**, 1921) report that no interference with the production of fruit takes place when apricots in flower are sprayed with lime-sulphur mixture or weak Bordeaux mixture, C. W. Edgerton ("Delayed Ripening of Tomatoes caused by Spraying with Bordeaux Mixture," *Louisiana Agric. Exper. Sta. Bull.*, **164**, 16 pp., 1918) found that spraying tomatoes with Bordeaux mixture brought about a delay of about one or two weeks in the ripening of plants which were kept well sprayed throughout the season. This is apparently due to the increased vegetative growth of the sprayed plants, a fact which has been recorded by other workers.

The premature dropping of flowers as a result of the action of known external conditions has already been mentioned. But premature shedding of fruit also takes place as a result of unknown causes, either internal or external. Thus M. J. Dorsey ("A Note on the Dropping of Flowers in the Potato," *Journ. Heredity*, **10**, 226–28, 1919) records that in many varieties of the potato both buds and opened flowers fall in large numbers. Although a large proportion of the pollen grains abort, the absence of the stimulation of pollination cannot be cited as the reason for the dropping of the flowers, as this takes place in many cases before pollination would normally be effected.

The same author has made a study of the shedding of flowers and young fruit in the plum (*Genetics*, **4**, 417–488, 1919). He comes to the conclusion that there are three distinct periods in which shedding of the flowers or immature fruits takes place. The first period occurs very shortly after flowering. Investigation of the fallen flowers shows that these contain defective gynæcia, and it must be concluded that this shedding of flowers is connected with the presence of the functionless gynæcia. A similar phenomenon has been observed in apricot trees and some varieties of plum growing in the neighbourhood of Vienna by J. Löschnig ("Die Verkümmerung der Aprikosenblüte," *Zeitsch. f. Garten- u. Obstbau*, **1**, 27–28, 1920), who concludes that the flowers exhibited starvation phenomena, the origin of which the author thinks is to be found in a shortage of phosphate in the soil.

The second period of premature fruit shedding occurs, according to Dorsey, about a fortnight after the first shedding. In this second series of prematurely shed gynæcia, the latter are normal, but apparently fertilisation has not taken place, either on account of the absence of pollination, or because pollen tube growth has been too slow. A third shedding of gynæcia or young fruits takes place later in which fertilisation has occurred, but growth of the embryo has become arrested.

Similar phenomena with regard to shedding of flowers and fruits occur in other species, as, for example, the cherry and some varieties of apple and pear, but other species show quite distinct relations with regard to premature shedding.

A number of investigations have been made during the last few years on the chemical changes taking place in fruits during ripening. Apples and pears have been investigated by E. L. Overholser and R. H. Taylor ("Ripening of Pears and Apples as Modified by Extreme Temperatures," *Bot. Gaz.*, **69**, 273–96, 1920), who find that in apples the rate of ripening is greater the higher the temperature, but that with Bartlett pears there is a definite retardation of the rate of ripening at temperatures of 30° C. and over. This retardation reaches a maximum at some temperature between 34·4° and 40°, at temperatures above this ripening proceeding more rapidly. Pears ripened above 30° C. are more acid and less sweet than those ripened at lower temperatures. J. R. Magness ("Investigations in the Ripening and Storage of Bartlett Pears," *Journ. Agric. Res.*, **19**, 473–500, 1920) also found that this same fruit kept at 30° F. had a lower acid content than that kept at 40° or 70° F. He also found more sugar present in pears stored at 30° than in those stored at 40° F. His results thus agree well with those of Overholser and Taylor.

Changes taking place during the ripening of tomatoes have been examined by C. E. Sands (" The Process of Ripening in the Tomato, considered especially from the Commercial Standpoint," *U.S. Dept. Agric. Bull.*, **859**, 38 pp., 1920). He finds that in general throughout the ripening period the percentage of water, acids, and sugars increases, whereas the proportion of total nitrogen, starch, pentosans, " crude fibre," and ash constituents decreases. Thus while sugars increased from 25·7 per cent. in young fruit (14 days old) to 48 per cent. in ripe friut, starch decreased in the same time from 15·8 per cent. to 2·7 per cent. Similar results were obtained by F. L. Dominguez (*Ann. Rep. Insular Exper. Sta. Dept. Agric. and Labour, Porto Rico*, 105–8, 1918) with regard to the chemical changes in ripening grape fruit.

**ZOOLOGY.** By Reginald James Ludford, Ph.D., B.Sc. (Lond.), University College, London.

*Protozoology.*—A new ciliate, *Balantidium blattarum*, which occurs as an intestinal parasite in the common cockroach, is described by E. Ghosh in *Parasitology*, vol. xiv, No. 1. This protozoon was found in the intestinal contents of cockroaches collected at Calcutta, and the writer states that it is comparatively rare in its distribution.

B. L. Bhatia continues his descriptions of fresh-water ciliate protozoa of India in the *Journ. Royal Micr. Soc.*, March 1922. Altogether forty-one species of ciliates have been described by this investigator, and only two of these have been recorded by previous investigators in India.

*Cytology.*—In a paper on " Surface Tension and Cell Division " (*Q.J.M.S.*, June 1922), J. Gray compares the surface-tension phenomena of dividing cells with oil drops during fusion and fission. He concludes that the cleavage furrow is the result of an equilibrium established between the movement of protoplasm induced by elongation of the axis of the cell due to separation of the asters and the surface tension at the cell surface. " There is no necessity to postulate regions of differential surface tension at the poles or equator of the cell."

" The Gametogenesis of Saccocirrus " is described by J. Brontë Gatenby in the *Q.J.M.S.*, March 1922. This is the first account published of the cytoplasmic organs during oögenesis in this Archi-annelid. The mitochondria and Golgi apparatus apparently play no direct part in yolk formation as occurs in some of the types previously described.

They do, however, divide and spread throughout the cytoplasm during growth of the oöcyte. The formation of yolk is essentially the function of the nucleolus, which buds off fragments into the cytoplasm and these lead to the formation of yolk spheres.

The behaviour of the cytoplasmic organs during spermatogenesis is similar in many respects to that in other organisms which have been studied. The mitochondria, however, fuse in the spermatid and later form the tail sheath, but the Golgi apparatus is possibly sloughed off. It may, however, be represented in the mature germ cell by granules which occur on the distal end of the tail. The tail of the sperm penetrates the egg at fertilisation, but Gatenby does not consider that these " tail granules " have any functional significance.

The probable part played by the cytoplasmic inclusions in inheritance is discussed in the same paper.

Since Montgomery's classical paper on the nucleolus was published in 1895, a large number of papers have appeared dealing with the structure and function of this cell organ. A critical survey of the new work is given by R. J. Ludford in the *Journ. Royal Micr. Soc.*, June 1922 (" The Morphology and Physiology of the Nucleolus," Pt. 1). The same paper also contains an account of the behaviour of the nucleolus in the germ cell cycle of the Mollusc, *Limnæa stagnalis.* Nucleolar extrusions are described during oögenesis, and in somatic cells during periods of special metabolic activity. The probability of the nucleolus having a special nutritional function in the cell is emphasised.

Other papers include :

(i) " Der Fettkörper und die Oenocyten von *Dytiscus marginalis,*" by Arthur Kreuscher (*Zeit. für Wiss. Zool.*, April 1922). Of special interest are the œnocytes, which have a system of fine secretory canaliculi extending from the nucleus radially to the periphery of the cell. " Es sind Zellen mit innerer Secretin."

(ii) " Beiträge zum feineren Bau der Purkinje' schen Fasern im Herzen der Vögel," by E. H. Tang (*Anat. Anz.*, 55 Band, Nr. 16, 17), in which is described the cytoplasmic organs of the cells of the " Purkinje' schen Fasern "—granular mitochondria, circum-nuclear Golgi apparatus and myofibrillæ.

(iii) " The Behaviour of the Golgi Bodies during nuclear division, with special reference to Amitosis in *Dytiscus marginalis,*" by R. J. Ludford (*Q.J.M.S.*, vol. lxvi, No. 261, March 1922).

*Histology.*—" Histogénèse et régénération du muscle chez les Anoures " is the subject of a paper by André Naville in the *Archives de Biologie,* April 1922. He points out that muscle fibres are formed of two parts, which are quite distinct with regard to their potentialities. There is the sarcoplasmic part containing numerous mitochondria and nuclei, and there is the characteristic specialised part composed of myofibrillæ. The former alone is capable of giving rise to regenerative buds, and it is to the loss of this part that the failure of muscles to regenerate at a certain age is due. " Il n'y a donc pas dédifferenciation à proprement parler" ; and in this case there is no parallelism between regeneration and ontogeny.

R. K. S. Lim has carried out an investigation on the histology of the gastric mucosa (*Q.J.M.S.*, vol. lxvi). In the cat, gastric glands arise from non-mucoid red staining cells which later become mucoid in character throughout the stomach. The mucoid cells of the fundus vary slightly in appearance in different animals. The mucoid type of cell gives rise to the peptic cells in the cat, and this probably is the case in other animals. The writer concludes that "the cells of the cardiac and pyloric glands may be regarded as cells which have been prevented from attaining full development by the conditions existing at the orifices of the stomach."

The various gastric cells are classified from the functional point of view as follows :

(i) Lowest type—the mucoid cells of the fundus with apparently no pepsin secretion.

(ii) Cardiac and pyloric cells—which secrete a proteolytic ferment, according to Klemensiewicz and Heidenhain, and exhibit a certain degree of zymogen formation.

(iii) Highest type—the peptic and oxyntic cells, the most highly specialised.

The terminations of the human bronchiole are described by H. G. Willson in the *Amer. Journ. of Anat.*, vol. xxx, No. 3. He finds " there is greater complexity, irregularity, and a greater degree of interlocking than is usually described."

Other papers include :

Clara, Max, " Kleine histologische Mitteilungen," *Anat. Anz.*, 55 Bd., Nos. 16, 17.

Lotzin, Richard, " Ueber die Bedeutung physikalischer Knorpeleigenschaften für die Vitalfärbung des Knorpels," *Anat. Anz.*, 55 Bd., Nos. 16, 17.

Naccarati, Sante, " Contribution to the Morphologic Study of the Thyreoid Gland in *Emys Europæa* (Turtle)," *Journ. of Morph.*, vol. xxxvi, No. 2.

Sonntag, C. F., and Duncan, F. M., " Contributions to the Histology of the Three-toed Sloth (*Bradypus tridactylus*), *Journ. R.M.S.*, March 1922.

*General and Experimental Embryology.*—In a paper " On the Heat Production and Oxidation Processes of the Echinoderm Egg during Fertilisation and Early Development " (*Proc. Roy. Soc.*, vol. xciii, No. B, 654), C. Shearer shows that there is an increase in oxygen consumption and in output of heat and carbon dioxide in the fertilised egg, which points to the fact that fertilisation leads to an increased liberation of the chemical energy stored up in the egg. However, the calorific quotient of the egg both before and after fertilisation is approximately the same; the writer therefore concludes that as a "negligible quantity of this energy is expended in bringing about the visible morphological structure of the developing ovum, it is probably employed in keeping the living substance itself intact as a physical system."

Hiroshi Ohshima describes in the *Q.J.M.S.* (vol. lxvi, March 1922) cases of situs inversus amongst artificially-reared echinoid larvæ. More than 10 per cent. of the larvæ reared exhibited this peculiarity, but the young sea-urchins metamorphosed from such larvæ were quite normal externally. In a note on the subject in the same journal, Prof. E. W. MacBride points out that while he brought about the development of a right hydrocœle in echinoid larvæ by stimulation with hypertonic salt solution, Ohshima's results are to be attributed to the checking of the growth of the normal left hydrocœle as the result of starvation.

The development of the branchial derivatives in turtles is the subject of an investigation by C. E. Johnson, "Branchial Derivatives in Turtles" (*Journ. of Morph.*, vol. xxxvi, No. 2, March 1922). Three genera were investigated: Chelydra, Chrysemys, and Trionyx. The persistent thymus arises from the dorsal part of the third visceral pouch. A cellular body—a possible rudimentary, transitory thymus—arises from the corresponding part of the second visceral pouch. From the fourth pouch, the persisting parathyroid is formed. A rudimentary transitory thymus probably arises from the same pouch, but the writer found no definite evidence of a persisting thymus arising from this region. Paired ultimobranchial vesicles are usually present at early stages; the left one usually grows larger than the other and often attains a considerable size. By the time of hatching, it has been transformed almost completely into a lymphoid organ which is quite distinct from the thyroid.

Other recent papers are:

Penners, Andreas, "Die Furchung von *Tubifex rivulorum* Lam.," *Zool. Jahr.*, Bd. 43, Heft 3.

Patten, B. M., "The Formation of the Cardiac Loop in the Chick," *Amer. Journ. of Anat.*, vol. xxx, No. 3.

Herrick, C. J., "Some Factors in the Development of the Amphibian Nervous System," *Anat. Rec.*, vol. xxiii, No. 5.

Stunkard, H. W., "Primary Neuromeres and Head Segmentation," *Journ. of Morph.*, vol. xxxvi, No. 2.

Lamont, A., "On the Development of the Feathers of the Duck during the Incubation Period," *Trans. R. S. Ed.*, vol. liii, Part I.

Ishii, O., "Observations on the Sexual Cycle of the White Rat," *Anat. Rec.*, vol. xxiii, No. 5.

Allen, E., "The Oestrous Cycle in the Mouse," *Amer. Journ. of Anat.*, vol. xxx, No. 3.

*Invertebrate Morphology* (excluding Entomology).—J. Stephenson continues his series of papers entitled "Contributions to the Morphology, Classification, and Zoogeography of Indian Oligochæta" in the *Proc. Zoological Society* (Pt. I, 1922). Part IV deals with the diffuse production of sexual cells in a species of chætogaster (Fam. Naididæ), and in Part V is given an account of the anatomy of *Drawida japonicus*, one of the Moniligastridæ, special attention being devoted to the nephridia and genital organs. The sixth part is "On the Relationships of the Genera of Moniligastridæ; with some Considerations on the Origin of Terrestrial Oligochæta." The writer criticises the view that the Phreoryctidæ, with five pairs of gonads and œsophageal gizzard, are the present-day representatives of the common ancestor. In the light of recent research he contends they are too specialised, and the discovery of Syngenodrilus points to the ancestral form having no œsophageal gizzard and a large number of gonads. The Lumbriculidæ more nearly resemble this type than the Phreoryctidæ.

The method of determining the number of segments of the Arthropoda, by counting from the anterior end of the body, is criticised by A. Petrunkevitch ("The Circulatory System and Segmentation in Arachnida," *Journ. of Morph.*, vol. xxxvi, No. 2, March 1922). In the case of the Arachnida, he suggests starting from the cardio-aortic valve, which marks the division line between the last thoracic and first abdominal segments. Applying this method to Limulus, he finds that the carapace is more complicated than in Arachnida, "having two abdominal tergites drawn into the horseshoe-shaped thoracic tergite, with which they have fused anteriorly and laterally." Adult Arachnida have seventeen post-oral somites, five thoracic and twelve abdominal, and the genital opening is on the second abdominal somite.

Other papers include:

Stephenson, T. A., "On the Classification of the Actiniaria, Part III," *Q.J.M.S.*, vol. lxvi, No. 261.

Sherriffs, W. R., "Evolution within the Genus Dendronephthya (Spongodes) (Alcyonaria), with descriptions of a number of Species," *Proc. Z.S.*, Part I, 1922.

Yokogawa, Sadamu, "The Development of *Heligmosomum muris*, Yokogawa, a Nematode from the Intestine of the Wild Rat," *Parasit.*, vol. xiv, No. 2.

Stolte, Hans-Adam, "Experimentelle Untersuchungen über die ungeschlechtliche Fortpflanzung der Naiden," *Zool. Jahr.*, Bd. 39, Heft 2.

Bahl, K. N., "On the Development of the Enteronephric Type of Nephridial System found in Indian Earthworms of the Genus Pheretima," *Q.J.M.S.*, vol. lxvi, No. 262.

Cannon, H. G., "On the Labral Glands of a Cladoceran (*Simocephalus vetulus*), with a Description of its Mode of Feeding," *Q.J.M.S.*, vol. lxvi, No. 262.

MONTGOMERY, S. K., "Direct Development in a Dromiid Crab," *Proc. Z.S.*, Part I, 1922.
OSTERLOH, A., "Beiträge zur Kenntis Kopulationsapparates einiger Spinnen," *Zeit. für Wiss. Zool.*, April 1922.
ROBSON, G. C., "On the Anatomy and Affinities of *Paludestrina ventrosa*," *Q.J.M.S.*, vol. lxvi, No. 261.
KRUG, C., "Morphologie und Histologie des Herzens und Pericards von *Anodonta cellensis*," *Zeit. für Wiss. Zool.*, April 1922.
RÖCHLING, E., "Der Kolumellarmuskel von Helix pom. und seine Beziehung zur Schale," *Zeit. für Wiss. Zool.*, April 1922.

*Vertebrate Morphology*:—W. H. Leigh-Sharpe continues, in the *Journ. of Morph.*, his series of memoirs on "the comparative morphology of the secondary sexual characters of elasmobranch fishes—the claspers, clasper siphons and clasper glands" (*Journ. of Morph.*, vol. xxxvi, No. 2, March 1922). Two memoirs on the same subject, dealing with the common British species, have already been published. The third memoir deals with the fossil forms, and the fourth and fifth with specimens which the writer was enabled to study at the Natural History Museum. The same writer describes in *Parasitology*, vol. xiv, No. 2, a curious tumour occurring amongst the gill filaments of *Trigla gurnardus* (the gurnard), which bears a female Medesicaste (a copepod), with the head and neck buried in its apex, and a male Medesicaste completely embedded in its base. The two sexes of the parasite are connected by a conjugation tube, external to the tumour, down which the spermatophores presumably pass.

R. Broom discusses the comparative anatomy of the temporal arches of the Reptilia in a paper in the *Proceedings of the Zoological Society* (April 1922). On the basis of his interpretation, he classifies the Reptiles in four subclasses:

(1) Anapsida—primitive types with a roofed temporal region, which includes the forms usually grouped as Cotylosaurs.

(2) Diapsida—including the primitive Eosuchia, Lacertilia, and Thalattosauria.

(3) Synapsida—mammal-like reptiles with a lower temporal fossa.

(4) Anomapsida—primitive lizard-like reptiles, with only the upper temporal fossa developed, and their aquatic descendants, the Mesosaurs, Ichthyosaurs, Plesiosaurs, and Placodonts. This sub-class also includes the highly specialised Chelonians.

Other papers include:

REGAN, C. T., "The Cichlid Fishes of Lake Victoria," *Proc. Z.S.*, Pt. I, 1922.
HORNYOLD, A. G., "The Age and Growth of some Eels from a small Worcestershire Pond," *Journ. R.M.S.*, March 1922.

SONNTAG, C. F., " On the Vagus and Sympathetic Nerves of the Edentates,"
SONNTAG, C. F., " On the Vagus and Sympathetic Nerves of *Hyrax capensis*," *Proc. Z.S.*, Pt. 1, 1922.

*General Experimental Zoology.*—A. Fleming has discovered a remarkable bacteriolytic element in tears, saliva, and sputum, and in most of the tissues of the body. It possesses the property of destroying microbes to a very high degree (*Proc. Roy. Soc.*, vol. xciii, No. 653, B).

L. T. Hogben and F. R. Winton, working on the reaction of the frog's melanophores to pituitary extract, have found that extracts of the posterior lobe of that gland, in quantities as small as one-thousandth of the ordinary clinical dose, cause expansion of the melanophores. This extract acts directly upon the melanophores, rather than on the nerve endings, as the reaction occurs when the nerve endings have been paralysed by drugs (*Proc. Roy. Soc.*, vol. xciii, No. 653, B).

An interesting series of investigations on animal pigments is the subject of a paper by J. F. Fulton in the *Q.J.M.S.* (vol. lxvi, June 1922). The pigments of the invertebrates appear to be derived from their food ; they are absorbed by the blood and carried by it to the epidermis, and there deposited. The writer considers that strong evidence exists that the respiratory pigment hæmoglobin is derived both phylogenetically and physiologically from chlorphyll. Such pigments as hæmoglobin are possibly synthesised from the four pyrrol groups of the chlorophyll molecule.

## ENTOMOLOGY.

By A. D. IMMS, D.Sc., Institute of Plant Pathology, Rothamsted Experimental Station, Harpenden.

*General Entomology.*—G. C. Crampton (*Proc. Ent. Soc. Washington*, **24**, 65–82) has a further contribution to his already numerous series of articles on insect morphology. In the present paper he discusses the first maxillæ of the Apterygota, comparing them with the corresponding appendages in Crustacea. He concludes that the basal segment of a crustacean buccal appendage forms the cardo of an insect's maxilla. The second segment, with its endite in the Crustacea, forms the stipes with the lacinia in insects, while the third segment with its endite in Crustacea forms the insectan palpifer with the galea. The terminal segments of the endopodite of the crustacean buccal appendage forms the palpus of the insect's maxilla. He regards it as incorrect to homologise the maxillary palpus of the insect with the exopodite of the crustacean limb, and the galea and lacinia of the insect with the endopodite of that limb. E. M. Walker (*Ann. Ent. Soc. Am.*, **15**, 1–88) contributes a lengthy paper on the terminal abdominal structures of orthopterous insects, and is of general interest to students of morphology. Among physiological papers, J. H. Bodine (*Journ. Exp. Zool.*, **35**, 47–55) has studied the effect of light on $CO_2$ using certain Orthoptera in the experiments. Loeb considers that the primary effect of light is to cause an alteration in the tension of muscles. Bodine's experiments indicate that the effect of light on the eyes, in changing the muscle tension, is associated with a decrease in the rate of the $CO_2$ output of the organism. T. J. Headlee (*Journ. Econ. Entom.*, **14**, 264–8) has observed the responses of *Bruchus obtectus* to varying percentages of atmospheric moisture. The air was led through $H_2SO_4$ to free it of moisture, and passed into a chamber which was maintained at 26·6° C. where the air was conducted through saturated solutions of various salts, which gave up to it the required moisture. In air containing 7·1 per cent. or less moisture few or no beetles attained maturity. If it contained 25·9 per cent. comparatively few matured, while between 89·7 and 100 per cent. growths of fungi on the food inhibited the emergence of the beetles. The optimum atmospheric moisture was found to lie between 80 and 89 per cent. Bouvier's *Psychic Life of Insects*, translated by L. O. Howard, has lately appeared and is of general biological interest. Although essentially elementary in its treatment of the subject, it co-ordinates a large number of scattered observations drawn very largely from recent work.

*Psocoptera.*—G. Enderlein (*Ent. Month. Mag.*, May 1922) has published the description of a new genus and species of scaly-winged Psocids, specimens of which came from Crowborough, Sussex. The insect is designated *Pteroxanium squamosum* and belongs to a subfamily only previously known from New Guinea and Ceylon. The occurrence of a representative in Europe is, therefore, very remarkable, and suggests the possibility that it is not indigenous but has been imported by some means or other.

*Anopleura.*—All students of this group will be interested in the very thorough anatomical and biological account of *Hæmatopinus suis* given by L. Florence (Mem. 51, *Cornell Univ. Agr. Exp. Sta.*). The general similarity of structure in the Anopleura and Mallophaga is borne out in this work, which thus affords support to the conclusions of Mjoberg and of Harrison. The second part of G. F. Ferris's contributions towards a monograph of the sucking lice has recently appeared [*Stanford Univ. Ser. Biol.*, **2**, (2)] and deals with the genus *Hoplopleura*. Nuttall and Keilin (*Parasitology*, **13**, 184–92) have made a careful study of the nephrocytes of *Pediculus*. The excretory function of these cells is demonstrated by the fact that granules of ammonia-carmine are taken up by them twenty-four hours after intra-cœlomic injection and remain stored in the nephrocytes throughout the life of the louse.

*Odonata.*—R. T. Tillyard (*Ent. News*, **33**, 1–7, 45–51) has investigated the tracheation of the developing wings in *Uropetala*, a dragonfly belonging to the archaic family Petaluridæ. He concludes that a complete re-study is necessary in order to bring the notation used in this group of insects in line with that used in other orders. The Odonata of South Africa form the subject of a monograph of F. Ris (*Ann. S. African Mus.*, **18**, 245–452). E. H. Hankin (*Proc. Cam. Phil. Soc.*, **20**, 460–65) discusses the soaring flight of dragonflies, which apparently does not depend either upon undiscovered wing-movements or on the use of ascending currents. Soaring flight occurs in dragonflies, flying-fishes, and birds : in each class evidence indicates that low-speed flight depends upon the presence of sunshine and high-speed flight on the presence of wind.

*Coleoptera.*—D. J. Jackson (*Ann. App. Biol.*, **9**, 93–115) contributes the second part of her work on certain weevils of the genus *Sitona*, recording among other features the occurrence of alary dimorphism in *S. hispidula*. F. Balfour-Browne (*Proc. Zool. Soc.*, 1922 (1), 79–97) has a valuable paper on the bionomics of the water-beetle *Pelobius tardus*. Bugnion (*Bull. Biol. Fr. et Belg.*, **56**, 1, 1. 53) writes on the anatomy and embryology of the larvæ of Lampyridæ, and describes the structure of the larva of *Luciola lusitanica* in detail in a separate paper (*Ann. Sci. Nat.*, 1922, 29–59). W. M. Wheeler (*Zoologica*, **3**, Nos. 3–11) writes on some social beetles of British Guiana and their relations to the ant-plant *Tachigalia*. If we regard as truly social only those insects in which the parent or parents live with their offspring, protect and feed them, there have been known hitherto but three groups of Coleoptera coming under this category—viz. the Passalidæ, Scolytidæ, and Platypodidæ. Prof. Wheeler, in the present contribution, adds two genera of Silvanid beetles belonging to the family Cucujidæ to this short list. The beetles enter the hollow petioles of a Leguminous tree Tachigalia and live a social life therein which the author discusses at length. The life-history of the Flax-beetle (*Longitarsus parvulus*) has been very thoroughly studied in a well-illustrated paper by J. G. Rhynehard (*Sci. Proc. Roy. Dublin Soc.*, 16). This species is a serious enemy of flax and one responsible for considerable loss to growers of the crop in Ireland. It is commonly found throughout Ulster, and of recent years has become a pest in flax-growing districts in Co. Cork. The adult beetle kills many of the seedlings by devouring the cotyledons and growing point of the flax, but will also eat clovers, grasses, and wild species of flax. The larvæ bore into and feed on the roots of the flax plants, but do not appear to cause any appreciable hindrance to growth. H. B. Weiss (*Amer. Nat.*, **56**, 159–65) summarises the feeding-habits of N. American Coleoptera, and estimates about 26 per cent. are phytophagous, 44 per cent. saprophagous, and 27 per cent. predaceous. He concludes that about three-fourths of the species are apparently engaged in what may be termed useful activity. The external anatomy of the Elaterid genus *Melanotus* forms the subject of a paper by R. H. Van Zwaluwenburg (*Proc. Ent. Soc. Washington*, **24**, 12–29). R. Jeannel (*Arch. Zool. Exp.*, **69**, 509–42) has an illustrated paper on the larvæ of cavernicolous beetles of the group Trechini, describing this stage in numerous species.

*Hemiptera*.—J. Davidson (*Ann. App. Biol.*, **9**, 35–145) has a further contribution dealing with the biology of *Aphis rumicis*. The reproduction of this species was tested on eighteen varieties of field beans and the results compared with the reproduction on Prolific Longpod broad beans. Five plants of each variety were tested, and the total number of aphids produced on each plant from one apterous viviparous female in fourteen days was counted. The mean values of infestation were found to range from 37 to 1,037, and they allow of the varieties being grouped into classes representing various grades of susceptibility, ranging from 98 per cent. to 3 per cent. Several additions to the Aphid fauna of Great Britain have been made during the last few months. F. V. Theobald (*Bull. Ent. Res.*, February) describes a new genus and species, *Laingia psammæ*, off marram grass and meadow foxtail in Kent. In *Ent. Month. Mag.*, June, the same author records *Trilobaphis caricis* ger. et sp. nov. off *Carex* near Bangor and F. Laing (*ibid.*, July) brings to notice three species not previously known from our islands.

*Hymenoptera*.—M. D. Haviland (*Parasitology*, **14**, 167–73) describes the larval stages of *Dacnusa areolaris*, a Braconid endoparasite of Diptera of the group Phytomyzinæ. The newly hatched larva is enclosed in a trophic membrane which is subsequently cast off; the caudate larva undergoes two ecdyses before assuming the typical grub-like stage. The same authoress (*Q.J.M.S.*, **66**, 321–38) discusses the metamorphosis of some Chalcid hyperparasites of Aphides and also certain general questions relative to insect parasitism. Among Hymenoptera it is suggested that this mode of life arose from an earlier inquiline existence. A. B. Gahan (*Proc. Ent. Soc., Washington*, **24**, 33–58) contributes a useful list of the species of phytophagous Chalcids (other than fig insects) known to date, and discusses the evolution of the plant-feeding habit within the group. H. Shapley (*Proc. Nat. Acad. Sci.*

*Philadelphia*, **6**, 687–90) writes on the persistence of traces of wings in worker ants, and in one nest of the red Californian Harvester ant over 1,700 workers were taken over a period of two years, nearly half of which exhibited vestigeal wings in various stages of development. In fifty other colonies within a radius of two miles only one of these pterergates was found. The author suggests that mendelian factors may be involved in the appearance of wings. R. Vogel (*Zool. Anz.*, **53**, 20–28) describes the olfactory organs of bees and wasps. In the queen bee he finds about 2,000 olfactory plates on each antenna, about 6,000 in the worker, and about 30,000 in the drone. The latter he maintains is thus well equipped for finding a queen for mating purposes. Each plate consists of about sixteen sensory cells innervated by very delicate nerve fibres.

*Diptera.*—Two detailed studies of the structure and biology of individual species have lately been published; one by A. E. Cameron on the Canadian Cattle-infesting Black Fly, *Simulium simile* (*Dep. Agric. Canada Bull.*, 5 n.s.), and the other by Chih Ping on *Ephydra subopaca* (*Cornell Univ. Agric. Exp. Sta. Mem.*, 49). In the latter publication, Memoir 44, B. P. Young has a technical paper on the attachment of the thorax to the abdomen in various Diptera. W. S. Patton (*Bull. Ent. Res.*, **12**, 411–26) has a first contribution to a revision of the species of *Musca*, dealing in the present instance with the Oriental and Australasian forms. In view of the rôle which members of this genus play in the dissemination of disease the exact determination of very closely allied species has assumed a practical importance. R. E. Snodgrass (*Proc. Ent. Soc. Washington*, **24**, 148–52) describes remarkable jaw-like lobes developed in relation with the labella of a Dolichopodid fly, *Melanderia mandibulata*. These organs are evidently used for seizing the prey, and bear an extremely close resemblance to true mandibles which they functionally replace. The genus and species bearing these organs are described as new by J. M. Aldrich in the same issue. M. Bezzi (*Parasitology*, **14**, 29–46) contributes a useful article summarising our present knowledge of Diptera whose larvæ are ectoparasites of birds, with particular reference to the genera *Passeromyia* and *Ornithomusca*. In the same journal H. M. Morris (pp. 70–74) describes the metamorphosis of a Phorid fly, *Hypocera incrassata*, parasitic upon the larva of *Bibio marci*. This appears to be the first definite record of an insect parasitic upon Bibionic larvæ. C. F. Ferris and F. R. Cole (*ibid.*, 178–208) write on various species of Hippoboscidæ which are well figured, and several forms are described as new. F. W. Edwards (*Ent. Month. Mag.*, May) describes a new genus and species of Cecidomyidæ, *Mycococcis ovalis*, from North Sussex. The early stages of this gall-fly are passed among bark-encrusting fungi, upon which they form blister-like swellings. It appears to be the first record of a Cecidomyid fly producing a fungus gall. The dispersion of flies by flight forms the subject of a paper by Bishopp and Laake (*Journ. Agric. Res.*, **31**, No. 10). An extensive series of experiments was carried out with several common species of Diptera, and an estimated total of 234,000 specimens was used. These were marked by being liberated into bags containing finely powdered red chalk or paint pigment and afterwards allowed to escape. In order to ascertain the distance of dissemination, baited traps were set at measured distances in different directions from the point of liberation. The experiments carried out show that under rural and urban conditions flies have marked powers of diffusion, which applies to both the sexes, although in very different proportions in different species. Thus the common house-fly, *Musca domestica*, was recaptured at a distance of over thirteen miles from the point of liberation, *Chrysomya macellaria* fifteen miles, and *Phormia regina* nearly eleven miles. The fact that many favourable feeding and breeding grounds were passed by the flies appears to indicate that, in so far as the above three species are concerned, very evident migratory habits are noticeable. The authors conclude that, under natural conditions, the influence of moderate winds on dissemination is not of great importance. K. M. Smith and J. C. M. Gardner have published a well-illustrated series of observations on the metamorphosis and control of three insects affecting vegetables—viz., the onion, carrot, and celery flies. The work forms vol. i of *Insect Pests of the Horticulturalist* (London, Benn Bros., 1922).

**PALÆONTOLOGY.** By W. P. Pycraft, F.Z.S., A.L.S., F.R.A.S., British Museum (Natural History), London.

Though the records of much valuable work have been published during the last six months, most of these are in the nature of details such as are filed for future reference. But among these are one or two memoirs of a more comprehensive character, and they call for special comment.

We are indebted to Dr. Gertrude L. Elles for an extremely interesting, and valuable, history of "The Graptolite Faunas of the British Islands" (*Proc. Geol. Assoc.*, vol. xxxiii, 1922).

While the Graptolites are generally regarded as allies of the Hydrozoa, Dr. Elles holds that it is by no means certain that they belong even to the Cœlenterata, and that they should therefore be regarded as forming a distinct class, the *Grapto-*

*lithina*, which must be divided into two orders: (*a*) Graptoloidea, (*b*) Dendroidea.

"It is noteworthy," she remarks, "that whereas the Graptoloidea seem to develop and change with somewhat startling rapidity, the Dendroidea appear to change scarcely at all, as regards their fundamental plan, throughout the greater part of Palæozoic time. . . . Therefore, in considering the question of the evolution of the group as a whole, it is with the Graptoloidea that we are specially concerned, and it is with the members of that order that the present paper deals."

The sections on the development of the embryo and on the stratigraphic value of evolutional stages will afford food for thought for many. A number of diagrams illustrating the various types add materially to the usefulness of this most admirable "Study in Evolution."

Dr. W. Leche, in a very suggestive memoir ("Morphologische-Geographische Formenreihen bei der Saugetiere," *Lund's Universitets Årskrift N.f. Ard.* 2, Bd. 16, No. 10, 1921), discusses a number of mammalian families, living and extinct, in which the oriental forms are shown to be more primitive than the occidental. He elaborates his arguments, as in the case of the porcupines for example, very ingeniously and convincingly. His conclusions agree very closely with those of Dr. Knud Andersen, based on the study of the Rhinolophidæ among the Chiroptera. Andersen's work, indeed, he is careful to point out, suggested his own researches. All geologists and palæontologists must read this survey.

Dr. C. W. Andrews' short paper on the bear of the Forest-bed (*Ann. & Mag. Nat. Hist.*) shows that this is not identical with the Cave-bear, as is commonly held. This is further and welcome evidence that the forest-bed fauna is entirely distinct from the later Pleistocene and recent faunas, a conclusion already advanced by Dr. Forsyth-Major, and Mr. M. A. C. Hinton, at different times and places.

Palæontologists and zoologists alike will welcome the final instalment of M. Revilliod's very valuable monograph of the Tertiary Chiroptera ("Contribution a l'études des Chiroptères des Terrains Tertiares," *Mem. Soc. Pal. Suisse*, Part III, xlv, 1922.)

**ANTHROPOLOGY.** By A. G. Thacker, A.R.C.S., Zoological Laboratory, Cambridge.

In the latest issue of the *Journal of the Royal Anthropological Institute* (vol. li, pt. 2, July—December, 1921), the most striking contribution is an article by Reid Moir entitled "On an Early Chellian-Palæolithic Workshop site in the Pliocene 'Forest

Bed' of Cromer, Norfolk." This is a paper of first-class importance. The reader will remember that the Strepyan and Chellean are the two oldest stages of the so-called Palæolithic age, though they are of course more recent than the Rostro-Carinate implements discovered by Moir, which date back to Middle Pliocene times. Now the geological date of the Chellean industry, and of the earlier Strepyan industry, has been a matter of long controversy. The great German glacialist, Penck, placed the Chellean in the second of his three interglacial periods, an interpretation which carries the corollary that the Aurignacian stage (which signalises the arrival of *H. sapiens* and the beginning of what Elliot-Smith has called the Neanthropic period) is to be placed in the third interglacial phase. On the other hand, the leading French pre-historians have placed the Chellean in the third interglacial, with the corollary that the Aurignacian comes after the fourth glacial phase. These two Pleistocene time-tables have long been well known and well understood by palæontologists. The two schemes are mutually exclusive, though certain writers have sometimes attempted to combine them. The matter remained in this condition for a decade and more, English geologists adhering either to the so-called German school or to the so-called French school. In particular, Sollas supported the French interpretation. During the last nine years I have referred to the question more than once in SCIENCE PROGRESS, and have indicated my reasons for adhering to Penck's scheme, with which the pioneer work of James Geikie was, in the main, remarkably congruous. During the last two years new English evidence has thrown additional light on the problem, and has revived the controversy. In the collection of this evidence, Reid Moir's work in East Anglia has held a most prominent place. He has found Chellean implements in Middle Glacial Sands and Mousterian implements in the Chalky Boulder Clay. He has correlated the Chalky Boulder Clay with the Riss (third) glaciation, and the Middle Glacial Sands with the Mindel-Riss (second) interglacial phase; and it seems to me that these conclusions are justified. (See SCIENCE PROGRESS for April and July 1921.) Moir therefore is in agreement with Penck. But the new finds are important in that they push the Chellean even further back. The Cromer Forest Bed is to be regarded as belonging to the first interglacial period, the second glacial phase itself being represented in East Anglia by the Cromer Till. The Chellean implements which Moir describes and figures in the above mentioned paper, are, therefore, one complete glacial cycle older than the great Chellean industry of the Continent. There is, of course, nothing especially surprising in this revelation; we should almost have expected that the Chellean industry would have existed sparsely for long ages before it became densely and widely spread in the Mindel-Riss interglacial. And, on the other hand, it may have persisted in some localities long after the Acheulean and Mousterian artefacts had appeared in more favoured districts. Nevertheless, the evidence now advanced is naturally of the highest importance and interest. But on one point a protest may be issued. It is true that the older geologists classed the Cromer Forest Bed as " Pliocene " ; but now that more is known of the correspondence of English and Continental strata, and since Moir himself agrees that the Forest Bed belongs to the Günz-Mindel interglacial phase, the use of the word " Pliocene " in this connection is obviously incorrect and misleading. The natural, as well as the conventional, commencement of the Pleistocene is at the Günz glaciation.

A discussion of this same subject has taken place also in recent numbers of *Man*. In the January number Mr. H. J. E. Peake wrote an article on : " The Ice Age and Man," and invited discussion. Peake agrees with the recently published opinion of M. C. Burkitt, that the Chalky Boulder Clay is Würm (fourth glacial), not Riss ; and he consequently adheres to the French scheme. He publishes a table which is intended to reconcile various authors by " revising " their results. The attempt is interesting, but not very successful. Geikie is revised out of all recognition. Geikie's " Mecklenburgian " was not represented by the Chalky Boulder Clay, and his Lower Turbarian had a Holocene fauna, and was therefore totally unlike the continental Bühl, which has a Pleistocene fauna. Moreover, Peake adds confusion to the subject by pushing even the Mindel-Riss interglacial phase back into the " Pliocene," and by applying the word Pleistocene to the Azilian age, with its notoriously Holocene fauna. In the April number Reid Moir replied to Peake. He republished his former correlation, and his scheme is in straightforward agreement with Penck. He published his views in the form of a definite geological table, which I would recommend those interested to study. There seems to me to be much probability in Moir's scheme, and the only criticism I would offer is that it is a doubtful proceeding to lump all the Red, Norwich, and Weybourne Crags together as Günz. The Red Crag is more probably a real Upper Pliocene stratum. In the May number Mr. C. E. P. Brooks, the meteorologist, also entered the arena. He says that the Mindel-Riss was the only real interglacial period, the only really warm phase in the Pleistocene, and hence that there were only two glacial periods, the Günz-Mindel (combined) and the Riss-Würm (combined), though each of these was " composed of several oscillations and readvances." He places the Chalky

Boulder Clay as the Mindel section of his Günz-Mindel Glacial phase. Finally, in July Dr. L. S. Palmer adds a contribution on "The Ice-Age and Man in Hampshire." His interpretation is quite unlike that of any of the other writers. He places the Chellean and Acheulean in the great Mindel-Riss interglacial phase, but makes the Aurignacian post-Würmian in date. He thus gets the whole of two glacial periods, and one interglacial period interposing between the Acheulean and the Aurignacian, a conclusion which is quite at variance with the continental evidence. The reader will perceive that he may select almost any opinion he may fancy. Penck's four-fold glacial scheme appears to withstand criticism, but how far we are from reaching finality in the English correlation is made apparent by the fact that competent writers cannot at present agree whether our great Chalky Boulder Clay is Mindel or Riss or Würm!

The contributions to recent numbers of the *American Journal of Physical Anthropology*, which is edited by Dr. A. Hrdlicka, continue to be of the highest scientific quality, though they are almost always of a very special character, and do not deal with general questions. This publication is coming to possess much the same position in physical anthropology as the *Journal of the Royal Anthropological Institute* has long held in social anthropology, and articles by non-American writers commonly appear in it. The "Notes" which it contains every quarter, and likewise the book reviews, will also be found to be useful sources of information.

The following papers may be noted:

In the *Journal of the Royal Anthropological Institute*, vol. li, pt. 2, July to December, 1921: "The Archer's Bow in the Homeric Poems: an attempted diagnosis," by Henry Balfour. (This was the Huxley Memorial Lecture for 1921.) "Animistic and other Spiritualistic Beliefs of the Bina Tribe, Western Papua," by A. P. Lyons. In the *Annals of Archæology and Anthropology*, vol. viii, No. 2, April, 1921: "The Roman Cemetery in the Infirmary Field, Chester" (Part 2) by R. Newstead, F.R.S. And in recent numbers of *Man*: "The Cephalic Index of the British Isles" by F. G. Parsons (February, 1922); and "Levirate and Kingship in India," by K. P. Chattopadhyay (March). And in the *American Journal of Physical Anthropology*, vol. iii, No. 4 (October—December, 1920): "Shovel-shaped Teeth," by Dr. A. Hrdlicka; and "The Form of the Parotid Gland in Japanese," by O. Chikanosuke.

**MEDICINE.** By R. M. Wilson, M.B., Ch.B.

*Sunlight and Rickets.*—Medical interest at present centres to a great extent on the study of rickets. This has undergone a rapid evolution since the discovery of the accessory food factors and notably of Vitamin A, the fat-soluble factor.

But an entirely new light on the subject has recently come through the labours of Dr. Harriette Chick and her co-workers in Vienna. Dr. Chick, practising at the Vienna University

Kinderklinic, discovered that the action of cod-liver oil on the bone lesions of rickets has an exact parallel in that of light. Not only so, but she was able to show that the important light element in this respect is the violet end of the spectrum.

This discovery led to the use of the mercury vapour quartz lamp instead of sunlight. It was found that this was capable of producing effects similar to the actinic solar rays and also to cod-liver oil.

It is notorious that cod-liver oil is rich in A Vitamin. Thus the question at once arises whether or not sunlight and other lights rich in violet rays are capable of producing A Vitamin by their action on the human skin, whether in short sunlight is not a food in a material sense of that term.

In any case Dr. Chick has used the expression photosynthesis to describe the phenomenon observed by her. She states in a communication on the subject to *The Lancet* that this is " an idea which is quite new to animal physiology."

It is interesting to apply this discovery to the known habits of mankind. Thus, in northern latitudes, where sunlight is a relatively infrequent meteorological condition, the intake of animal fats and oils by the inhabitants is large. Near the tropics, on the other hand, animal fats are but lightly partaken of. One might crystallise that into the phrase: " More light less fat."

Interesting, too, is the relation of the discovery to rickets itself. This abounds in towns such as Glasgow where the atmosphere is constantly charged with smoke and where, in consequence, the violet rays of the spectrum are excluded. It is much less frequent in sunny, open towns where there is a full supply of direct, unfiltered sunlight.

Dr. Chick suggests that the fact that rickets is not common in Greenland may be explained by the large consumption of cod-liver oil and other fish oils in that country by mothers and children.

In this connection the annual report of the Imperial Cancer Research Fund for 1921 raises some interesting new points. An attempt was made by one of the workers to test the effect of a lack of Vitamin A in the diet of animals. It was found that there resulted a definite diminution in the number of blood platelets, and that this diminution was accompanied by a susceptibility to the attacks of organisms normally not possessed of pathogenic power.

This condition exactly corresponded to that seen in X-ray and radium workers subjected to over-exposure. In other words, X-rays and radium would appear to occasion the same evil effects as loss of Vitamin A, while the violet rays of the sun occasion the same good effects as its restoration to the food.

It is manifestly much too early to draw any sort of conclusion from those very fascinating studies. Yet the curious fact of the publication of these two discoveries within a few weeks of each other may be commented on. If light may be food, it may also, in a different form, amount to starvation.

The Cancer Research report deals also with attempts to grow various tissues *in vitro*. This was not found to be possible unless there had been added to the culture fluids an embryonic substance of unknown composition. In the presence of this substance growth took place. Yet, so far as parenchymatous tissues were concerned, no differentiation could be detected unless and until connective tissue elements were present. A vast field is opened up here.

Another interesting piece of work was that which culminated in the discovery that cancer cells appear to produce some body exercising a highly poisonous effect on them. Thus, if the piece of malignant growth is not removed at frequent intervals to new media it perishes. Curiously enough, normal tissue is not affected in this way and will continue to grow on media where cancer has been growing, but in which it cannot longer maintain itself. Efforts are being made to determine the nature of this poison, which seems to possess the important quality of killing cancer cells but not the normal cells of the organism.

**EDUCATION.** By A. E. Heath, M.A., University, Liverpool.

The writer of these notes has received certain comments on the remarks (Science Progress, July 1920, p. 47) concerning the relation between the personality of the teacher and the improvements in method which come from educational experiment and research. It was there contended that " personality " —which involves the same elements of self-control that are reflected in the control of subject-matter we call method—is of co-ordinate importance with the rational study of educational processes. The basis of the criticism is the statement that this view does not give to personality the place to which its fundamental importance entitles it. " A teacher," it is claimed, " either has or has not a suitable personality which is his irrespective of the methods he uses and which is a product crystallising out of the whole man's ' attitude ' or ' philosophy ' or ' religion.' " Now I am at one with the critic in believing in the importance of personality ; but I am not happy about the implied disjunction between the teacher's personality and his methods. I cannot agree that, somehow or other, an attitude or a philosophy or a religion appears or crystallises out of the void. Surely the final flower of personality is a product of long and often painful experience in the world of real events. Biologically the development of individuality—and finally, by the emergence of self-consciousness, of personality—is a matter of hard struggle and of successive adaptations. The hard work that goes to the creation of craftsmanship in teaching may, indeed, lead only to technical skill; but it is, nevertheless, a pre-condition of any valuable "teaching personality." The craft of teaching (and the rational thought about that craft which alone lifts it above routine skill) is not, on this view, a mere mechanical adjunct to personality. It is the very stuff out of which, if it develops at all, a suitable teaching personality emerges. If technical craftsmanship is not crowned with this, it is barren; but personality in a vacuum, without its concrete basis, is unthinkable.

The whole issue is well worth serious thought, because it not only raises questions of fundamental importance in educational theory, but also determines our practical attitude towards such matters as the training of teachers. Belief in the value of training rests on the assumption that teachers should themselves be students of their craft; that theory, arising out of "practice conscious of itself," can illuminate such practice; and that craftsmanship may, in turn, quicken theory. It is fatal to overlook this interaction between art and science in any field. We must, on the one hand, admit that every art is a science, unless we are willing (as Plato puts it) to agree with the multitude that art is "a mere guessing and aiming well." On the other hand, the sciences have their origin in the world's work; and it is essential that we should remember this, even when science "seems to float in the clouds, serenely isolated from the hum and bustle and occupations of the busy world, and developing in some mysterious manner of its own" (Benchara Branford, *Janus and Vesta*, p. 185). It is true, Mr. Branford adds, that the thinker must occasionally seek a cloistral retirement for elaboration and systematisation; but only to return for refreshment and readjustment to the concrete labours in which his science has its roots. "Science," he says "is born anew in that wonderful world within each man, when with deliberate will he succeeds in thinking about the principles of his work in the great world without in a clear, logical, and systematic way, and courageously puts his conclusions to the test of experiment." The claim that, in this sense, education is itself a science—"an autonomous study, with its own special difficulties and subject-matter, and not a mere dumping ground for other sciences" (Science Progress, July 1920, p. 46)—must not, however, be taken to mean that it is *only* a science. Wider social and ethical problems are involved in any discussion of educational ends; and even if we confine ourselves to the question of means for attaining those ends, it is obvious that education is also an art. Again, Mr. Branford's able and suggestive chapter on "Science and Occupation" enables us to clarify our ideas through his conception of levels of skill. At the lowest level we have *routine skill*, an unconscious product of mere practice. *Scientific skill* is more than this: there is the addition of rational thought about practice; and the consequent understanding brings added power. Directed by consciously acquired principles skill becomes deliberate and communicable by language. A science is born. But there is a still higher level in this hierarchy: that of *æsthetic skill.* The word is used of course in a very wide sense, and is as applicable to the work of a physicist or mathematician as to that of an artist. It consists in the possession of what Prof. Whitehead has called that most austere of all qualities—a sense of style. It is the elusive "rightness" which distinguishes the work of the artist from that of the practitioner, and is incommunicable because it reflects the individual and unique quality of its possessor. This highest and final form of skill does not necessarily crown scientific skill. It is not, in other words, a certain outcome of education; but education may aid or thwart its development.

The question at issue can now be put in plain terms. To the teacher, educational science is a servant whose usefulness grows with his own growth in experience and skill. Its function is to help him to convert the daily round of an "honest, bread-winning *occupation*" into a self-conscious and rationally guided *profession.* But the final step to a true *vocation,* though dependent for its fruition on these earlier stages, is not an inevitable outcome of them: it is only mediated by the appearance of the "something more" we call æsthetic skill. The work of the genius, be he physicist or teacher, is recognisable at a glance in its unique completeness and rightness. But to admit *that* is not, it seems to me, inconsistent with the supposition that both a science of physics and a science of education is within the realm of the possible.

The following is a selection of references to recent work:

Otto Lipmann, *Brit. Journ. of Psy.*, 1922, **12**, 4, pp. 337–51, "The School in the Service of Vocational Study." As a result of his own work the author concludes that the school may perform very valuable and special service in the cause of vocational guidance; not only in positive ways, but also in warning pupils not to leave choice of occupation to chance circumstances or mere custom.

E. C. Oakden and Mary Sturt, *Brit. Journ. of Psy.*, 1922, **12**, 4, pp. 309–336, "The Development of the Knowledge of Time in Children." Up to eleven the conventional names of time-periods, and especially of dates,

have little meaning for children except when correlated with the child's own activities. This has obvious bearing on the teaching of history and the use of such aids as time-charts. In this connection it might be mentioned that a very interesting chart, which would be of value also to science teachers, has been designed by Mr. Reeves: *The World Story of* 3,000 *Million Years* (P. S. King, 1922).

THE MASTER OF BALLIOL, *School Science Review*, 1922, **3**, 11, pp. 85–101, "Science and History." A reprint of the racy address to the Science Masters' Association on the relations between history and science.

CYRIL BURT, *Journ. of Exp. Ped.*, 1921, **6**, 2, pp. 66–75; **6**, 3, pp. 142–155; 1922, **6**, 4, pp. 212–24, "The Dreams and Daydreams of a Delinquent Girl." Continuations of the article mentioned in SCIENCE PROGRESS, July 1921, p. 44.

W. H. WINCH, *Journ. of Exp. Ped.*, 1921, **6**, 3, pp. 121–141; 1922, **6**, 4, pp. 199–212; **6**, 5 and 6, pp. 175–287, "Children's Reasonings: Experimental Studies of Reasoning in School-children."

H. BOMPAS SMITH, *Journ. of Exp. Ped.*, 1921, **6**, 2, pp. 59–65, "A Theory of the School." Starting from the definition of the school as the home of the ideal, Prof. Bompas Smith develops a closely reasoned and far-reaching treatment of modern educational problems.

A. N. WHITEHEAD, *Journ. of Exp. Ped.*, 1922, **6**, 4, pp. 191–99, "The Rhythm of Education." An important address on the principle that modes of study should be adapted to the child's stage of mental development. Prof. Whitehead criticises the adequacy of certain ways of "ordering" a study—*e.g.* the order of difficulty—and puts forward the idea of cycles of intellectual progress consisting of the stages of romance, precision, and generalisation.

# ARTICLES

## THE SPECTRUM OF HYDROGEN

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Hydrogen is known to emit several totally distinct spectra. Of these the most frequently observed is a series spectrum in the visible and ultra-violet regions, which is accompanied by other related series in the infra-red and far ultra-violet. An entirely distinct line or band spectrum is observed under suitable conditions, which is called the secondary spectrum. It is not so intense as the series spectrum, but contains a large number of lines. There is also a continuous spectrum, observed in hydrogen-filled vacuum tubes, but of which little is known, except that its intensity distribution precludes it from being a temperature radiation.[1]

The chief object of this article is to describe some recent work on the secondary spectrum, but an account of the series spectrum will not be out of place.

The main series of hydrogen, usually known as the " Balmer" series, is of exceptionally wide occurrence. It is found in nebulæ and remains a prominent feature of several later types of stars, such as Sirius and $\delta$-Aquilæ. Its prominence in the sun is evident from the fact that Fraunhofer chose the first three lines of the series, $H\alpha$, $H\beta$, and $H\gamma$, to mark the C, F, and G regions, in his classification of the solar spectrum. The red C line is responsible for the red colour of solar prominences, and has been observed at a height of 8,000 km. above the normal photospheric surface.

In the laboratory the Balmer series is obtained from vacuum tubes—indeed it is rarely absent from them—and also from the arc and spark in hydrogen. Curiously enough, it has rarely, if ever, been observed in flames. The spectrum of burning hydrogen gives only a series of bands in the ultra-violet, which are commonly attributed to water-vapour. The introduction of hydrogen salts, such as hydrogen chloride, into flames does

[1] *I.e.* a continuous spectrum emitted by an opaque body in virtue of its temperature alone, in which the energy distribution obeys Planck's Law.

not result in the emission of the Balmer lines, but it is stated that they are present in the flame issuing from a Bessemer converter.

As has been mentioned, there are other series closely associated with the Balmer series. There is one in the infra-red, and another in the far ultra-violet, which can only be photographed in a vacuum spectrograph, since a thin layer of air absorbs completely light of such wave-lengths. Yet another series has recently been announced in *Nature* from Prof. R. W. Wood's laboratory. It lies in the far infra-red, and its existence was predicted, and the wave-lengths calculated, from the previously known series, from a theoretical standpoint.

The Balmer series has been of fundamental importance to the development of spectroscopic theory. It was in this spectrum that a mathematical relation was first found which would connect the wave-lengths of the constituent lines. From the early days of the spectroscope spasmodic attempts were made to discover some law to govern the spacing of the lines observed, and a few fragmentary regularities were soon detected. It was not until 1885 that Balmer discovered a formula which expressed—and with surprising accuracy—all the members of the series spectrum of hydrogen. His formula, discovered quite empirically, is given by

$$\lambda = h \times \frac{m^2}{m^2 - 4} \times 10^{-8}$$

where $\lambda$ is the wave-length of the line, $h$ is a constant, and $m$ is given successively the integral values 3, 4, 5, 6,— — — —, to calculate the individual lines. The strongest line is in the red (H$\alpha$, or the C line) and is obtained by putting $m$ equal to three. The lines represented by higher integers obviously get closer and closer together towards the ultra-violet, and their intensity diminishes very rapidly in the same direction. Only the first eleven members were known to Balmer, but now more than thirty have been traced in stellar spectra. This number has not been approached in the laboratory, but Prof. Wood by using a vacuum tube of a peculiar type has succeeded in photographing twenty members. The Bohr theory suggests that an upper limit may be set to the number of lines of this series which can be developed in a vacuum tube, as the diameter of the electronic orbit required for the emission of the higher members becomes comparable with the free path of the molecules.

It is outside the scope of this article to describe the advances springing from Balmer's discovery, such as the disentanglement of similar series from other spectra, and the recasting of his formula into a generalised form by Rydberg and others. This subject has recently been treated at considerable length in a monograph by Prof. Fowler.

The source of the Balmer series is known very definitely to be the hydrogen atom. This conclusion was at first merely a judicious guess from the conditions of excitation of the spectrum in the stars and the laboratory. It received experimental support later, from Fabry and Buisson's measurements of the broadening of the lines by the Doppler effect.

The hydrogen atom, according to modern conceptions, consists of a central positive nucleus, round which rotates a single electron. It is the simplest known atom, and it is not surprising that the spectrum it emits was the first to be explained on theoretical grounds by Bohr.

The secondary spectrum has hitherto gained only a modest degree of prominence. For a long time it was even suspected of an origin other than hydrogen, but this doubt was removed by an elaborate investigation of Dufour's, early in this century. The spectrum has been observed only in vacuum tubes.[1] It is an interesting fact that the purer the hydrogen in a vacuum tube, the stronger is the secondary spectrum relative to the Balmer lines. The latter never disappear, but in pure hydrogen with an uncondensed discharge the absolute intensity of even $H\alpha$ may be less than that of neighbouring secondary lines. The enhancement of the Balmer lines by impurities is an effect possibly closely allied to chemical catalysis. The pure hydrogen used in such spectroscopic experiments is the gas obtained by diffusion through palladium. The vacuum tube is first brought to an X-ray vacuum—by charcoal immersed in liquid air or some other means—and then a palladium tube attached to it is heated in the base of a Bunsen burner, where the partial pressure of hydrogen is high. Hydrogen then flows into the tube through the metal, which is, of course, impermeable to all other gases. If the palladium is heated in the very tip of the flame, where the hydrogen has all been oxidised, the gas which has passed into the vacuum tube may be extracted again, leaving a vacuum as good as the original. Palladium acts as a reversible hydrogen valve.

To return to the secondary spectrum, most of this is now definitely known to originate from the hydrogen molecule, $H^2$. It is possible that other complexes of hydrogen atoms may be represented among the weaker lines. Such complexes as the $H_3$ of Sir J. J. Thomson, and the active hydrogen described by Wendt, may be present in the tubes, but their contributions to

[1] Prof. Merton and the writer have attempted, but unsuccessfully, to obtain evidence of secondary hydrogen lines in the solar spectrum, by a comparison of Rowland's solar wave-length tables with their own wave-length measurements in the hydrogen spectrum.

the spectrum, if any, are unknown. It is now usually assumed that molecules emit band spectra, while series spectra are characteristic of atoms. $H_2$ is the simplest possible molecule, and its spectrum must be the prototype of band spectra, as the Balmer series is of series spectra. The spectrum emitted by an atom or molecule is at present the best weapon we possess for the attack upon its constitution. It is, therefore, justifiable to assume that the secondary hydrogen spectrum is destined for the same part in the elucidation of molecular mechanics that the Balmer series has already played in the investigation of the atom. Several attempts have already been made to calculate the wave-lengths of the secondary lines from various models of the hydrogen molecule, but in all published instances the calculated and observed values have disagreed completely. The reverse procedure of devising a model of the molecule from a study of the spectrum has so far been impossible, because too little has been known of the structure of the spectrum itself. It was on account of its probable theoretical importance that Prof. Merton and the writer have recently (*Phil. Trans.*, 1922) carried out an extended investigation of this spectrum, in the hope of preparing the way for its discussion by the mathematical physicist. The work has included a study of the wave-lengths and other characteristics of the lines, and a proof that the spectrum is actually due to the hydrogen molecule, about which there had previously been some doubt.

It has already been stated that the secondary spectrum is very rich in lines. There is in fact an average interval of only two or three Angstrom units between the lines which are included in the range λλ 6,000–4,000 A. It is necessary to have accurate wave-length measurements in such a spectrum, before searching for mathematical relations among the lines, for the ease of finding spurious regularities increases rapidly with the probable errors in the wave-length tables and the number of lines in the spectrum. The wave-lengths of as many lines as possible were accurately determined to diminish ambiguities of this type. It is, perhaps, worth while describing the procedure adopted in such measurements. Modern wave-length measurements are always made from spectrum photographs, and not visually. The light is dispersed by a Rowland concave grating, and the spectrum photographed on a plate suitably sensitised over the required spectrum range. The spectrum of the iron arc is next photographed on the same plate, which must not be moved in the interim. The unknown wave-lengths can then be deduced from the positions of the lines relative to certain iron lines, the wave-lengths of which have been determined accurately once and for all, and are accepted as international standards. The positions of the lines on the plate are read off under a travelling microscope, which is usually graduated to read to ·001 mm. It takes some practice to make accurate micrometer settings, and those made by an observer new to the work are usually unreliable for the first few months. Wave-lengths determined in this way should be correct to a few hundredths of an Angstrom unit.

Over 1,200 lines were measured in the secondary spectrum, and it would obviously require a jig-saw expert of superhuman ability to distinguish, by mere inspection, the related lines in such a tangle. It is fortunately possible to simplify the problem by studying the physical behaviour of the lines. It has been found that all the lines belonging to the same series in the spectrum of an element show similar Zeeman effects, are broadened to about the same extent by a condensed discharge, and are enhanced or weakened together by changes in the conditions of production, while the behaviour of the different series is quite distinct. Since this fact was observed it has been employed in the discovery of series in complicated spectra. Another criterion for related lines is that the intensities in a band or series alter continuously from member to member without any sudden break; but this is of more assistance in testing suspected regularities than in their discovery in the first place. The lines of the secondary spectrum can certainly be divided into several groups of lines of similar behaviour. The intensity distribution in the spectrum is, for example, completely upset by the introduction of helium into the hydrogen vacuum tube. Most of the lines are weakened, but a few are very much enhanced, and some totally new ones—undoubtedly due to hydrogen—make their appearance. It may be expected that some regularity will be found from a study of the small number of lines which are enhanced. Similar groups were distinguished by intensity changes in the spectrum when the pressure in the discharge tube was altered from about 0·1 mm. to 50 mm. of mercury, and by changes when a condenser and small spark-gap were introduced into the exciting circuit. Previous work by Dufour showed that some of the lines exhibited a Zeeman effect, while others were quite unaffected in a magnetic field; it is also known that some of the lines show a Stark effect.

Even with all these indications to assist, the structure of the secondary spectrum remains an open question. The only known regularities are still the few constant wave-length differences which Fulcher observed among some of the stronger lines, several years ago. One difficulty is of course that we do not know exactly what kind of regularity to expect. There is no doubt that a solution of the problem will rapidly be followed by important advances in our knowledge of molecular constitution.

An account of the evidence for the molecular origin of the secondary spectrum has been left to this point for the sake of clearness. The assumption was made in the first place because the Balmer series was known to come from the hydrogen atom, and the total dissimilarity of the two spectra denoted a distinct source. There is a very beautiful method for settling such questions quantitatively, the theory of which has been discussed very fully by Lord Rayleigh. The radiating particles in a gas are moving with velocities governed by the Maxwell distribution law. The light that they emit will, therefore, not be monochromatic to an external observer, but will be spread over an appreciable wave-length range by the Doppler effect. The average number of particles with any given velocity in the line of sight can be worked out from Maxwell's law, and the intensity of the light they emit is clearly proportional to their number. Every spectrum line, then, must have an intensity maximum, on either side of which the intensity falls off according to a definite law, which is actually

$$I_x = I_o \times e^{-kx^2}$$

where $I_o$ is the intensity at the maximum, $I_x$ the intensity at a wave-length distance $x$ from the central maximum, and $k$ is a constant. Now the mean velocity of the molecules of a gas, at a given temperature, is inversely proportional to the square root of the molecular weight, and so the magnitude of the Doppler effect, and the corresponding broadening of the line, are functions of the molecular weight of the radiating particles, and their mean temperature. It is usual to express the breadth of a line in terms of the distance on either side of the central maximum in which the intensity drops to half its maximum value, *i.e.* in the above formula it is the value of $x$ which makes $I_x/I_o = 0{\cdot}5$. It is known as the "half-width" of the line. Rayleigh arrived at the expression

$$\delta\lambda = \lambda \times k\sqrt{\frac{T}{M}}$$

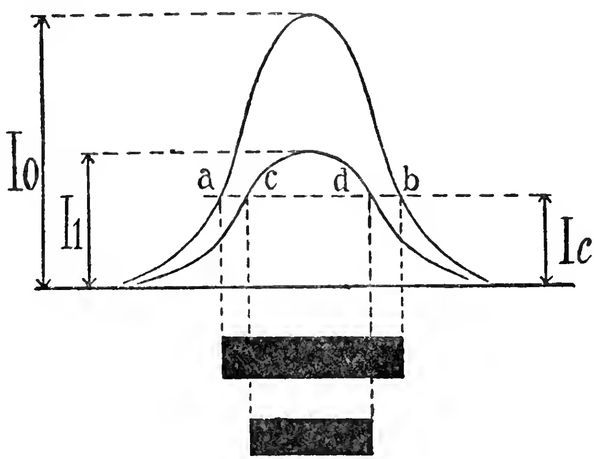
where $\delta\lambda$ is the half-width of a line of wave-length $\lambda$, T is the absolute temperature,[1] M is the molecular weight of the radiating particles, and $k$ is a constant.

This means that the mass of the particles responsible for a spectrum can be determined by measuring the half-widths of its lines. Such measurements are not easy to accomplish. The half-widths of the lines due to the hydrogen atom, where M has its minimum value, are only of the order of 0·05A, which is well

[1] It has been shown by Michelson that the mean temperature of the radiating particles in a vacuum tube is no higher than that of the walls of the tube.

beyond the resolving power of almost all grating, and certainly all prism instruments. Michelson, and later Fabry and Buisson, applied the interferometer to measurements of this nature. The difference in wave-length corresponding to successive fringes in any form of interferometer diminishes as the order of interference is increased. Now we have seen that a spectrum line is not strictly monochromatic, so the light from different parts of the line will overlap as the order of interference is increased, and finally uniform illumination will result. The number of fringes visible before this happens bears a known relation to the breadth of the spectrum line, and by counting them Michelson actually deduced the half-widths of a number of lines. This application of the interferometer has produced very valuable results, but it suffers from its dependence on personal estimates of the point at which the fringes become invisible, and the practical difficulties are great when dealing with faint and closely packed spectrum lines. For these reasons, half-width measurements in the secondary hydrogen spectrum are unsatisfactory if made by this method, and the half-widths of a few lines have now been redetermined by Prof. Merton and the writer, using an entirely new method, with results pointing conclusively to the molecule of hydrogen as the source of the spectrum.

The principle underlying the new method is the existence of a "critical photographic intensity." The density of the photographic image of a source of light, for a fixed time of exposure, is not proportional to the intensity of the light, but decreases much more rapidly than does the intensity, owing to the peculiar "law of blackening" discovered by Huerter and Driffield. If an extended source of light is taken, in which the intensity falls off gradually to zero on either side of a maximum, the photographic image will not fall off in intensity in quite the same way. It will have a fairly sharp boundary on either side, where the incident light has diminished to a critical intensity below which it is unable to affect the plate, and above which it produces a comparatively dense image (the absolute value of this critical intensity depends of course on the time of exposure). The sharpness of the boundary can be increased by using special plates made to give strong "contrast," by developing in strongly alkaline hydroquinone, and by chemical treatment subsequent to development. A spectrum line under a sufficiently high dispersion forms just such an image, owing to the Doppler broadening, and the width of this image depends on the distance, on either side of the central maximum, at which the intensity has dropped to the critical value. Suppose two successive photographs of a line are taken on adjacent parts of the same plate, and are given the same time of exposure, and the same development, etc. (to ensure the critical intensity being the same for each), but in one case the intensity of the source is cut down to a known fraction of its value in the other. Then the first image will be narrower than the second, because the same critical intensity must be reached at points nearer the central maximum, when the whole source is weaker. The difference in the width of the images is a known function of the half-width of the line, and the dispersion of the spectroscope used. The diagram will probably explain the method more clearly than a longer description.




The two curves represent the intensity distribution of the light in the spectrum line; the outer one is when the full intensity of the source is used, and the inner one is when this intensity has been cut down, *e.g.* by a screen, to the fraction $I_1/I_0$ at all points. We have seen that a critical photographic intensity exists. Let this be represented by the ordinate $I_c$. This intensity is reached at the points *ab* and *cd* respectively on the two curves, and the plate is blackened between these points only. The successive photographs will therefore present the appearance of the blackened areas underneath the main diagram. Owing to their sharp edges, the widths of the images can be read very accurately under the micrometer, and so a method of determining half-widths is provided in which the personal factor is reduced to a minimum. Any spectroscope of sufficient dispersion and resolving power can be used. The interferometers used in the other method are available, or the Lummer-Gehrcke plate. Actually the instrument employed for the secondary lines was a 35-plate echelon spectroscope, which is peculiarly convenient for the purpose. It can be set in two positions, in one of which it gives two equally intense images of the line under investigation, and in the other only one image. The positions are called the "Single" and "Double Order" positions respectively, and the intensities of the images in the two positions differ in a known ratio, which is exactly what is required for the half-width measurements.

The experimental procedure is simply to take two photographs of a line on the same plate, with equal exposures, but with the echelon set in the two different positions. Six micrometer settings are then made on the edges of the images, and the half-width is calculated. The table shows results obtained by this method.

| Line. | Observed half-width. | Calculated half-width. For H atom. | For $H_2$ molecule. |
|---|---|---|---|
| λ 6018 | 0·034A. | 0·046A. | 0·032A. |
| λ 6028 | 0·033A. | 0·046A. | 0·032A. |
| λ 6225 | 0·035A. | 0·048A. | 0·034A. |

The lines measured were chosen from the more important of the physical groups distinguished above, and the method was tested by applying it to a helium line, where the mass of the radiating particle is known. It is fairly safe, therefore, to assume a molecular origin for the secondary spectrum, in attempting to treat it theoretically.

In conclusion, reference must be made to some very curious observations on the distribution of the hydrogen spectra in vacuum tubes. Prof. Wood, in the attempt to extend the Balmer series beyond its normal laboratory limits, prepared a vacuum tube with a very long capillary. On filling the tube with hydrogen, the discharge was at first bright red throughout the capillary, and the predominant feature everywhere was the Balmer series. After running the tube with a powerful current for some time, its appearance changed. The discharge became white at the ends of the capillary, and, in the spectroscope showed mainly the secondary spectrum. The centre of the tube was still ruddy owing to the intensity of H*a*, but the white discharge gradually encroached upon it, and finally filled the whole tube.

Prof. Merton at about the same time observed a peculiar phenomenon in helium tubes containing—as they usually do—a trace of hydrogen. With a normal uncondensed discharge, the Balmer lines and the secondary spectrum, if it is visible, are equally intense all along the capillary. If a condenser is introduced momentarily into the circuit, on removing it again the distribution of the hydrogen lines is found to be disturbed. They show only at the ends of the capillary, but in a few seconds they work their way back to the centre. Further investigation revealed that the spectra of elements other than hydrogen, behave in the opposite fashion in a helium tube. After the condenser is removed they show only in the centre of the capillary, but gradually spread outwards. Oxygen, mercury, and sulphur lines behave in this way. These experiments point to an actual separation of the elements, caused by the condensed discharge, hydrogen being " blown out " of the capillary, and the other elements collected into it. These phenomena are very probably connected with those observed by Wood. The current densities he employed in his long tubes were very high, and one effect of introducing a condenser into a circuit is to increase the current density while the discharge is actually passing. If the densities he used were sufficient to drive the heavier atoms of the impurities to the centre of the capillary, they would there " catalyse " the production of the Balmer series, in virtue of the effect described earlier in the article, and the ends of the capillary would contain hydrogen sufficiently pure to exhibit a strong secondary spectrum. As the tube was run, the impurities would gradually disappear, and the Balmer lines would be weakened throughout the tube. No explanation of these observations has yet been given, and there is a clear field for further experimental work.

# ARABIC CHEMISTRY

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It is astonishing to find how very little definite knowledge we possess of the development of chemistry in the period of Islamic pre-eminence, a period which may roughly be taken as extending over seven centuries from the date of the Flight of the Prophet MUHAMMAD to Medina in A.D. 622. Up to the last decade of the nineteenth century, the early Arabs (or rather Arabic-writing authors) enjoyed an extravagant reputation as chemists, largely on the basis of certain thirteenth and fourteenth century Latin works which were considered to be translations from the Arabic. When, however, in 1893, Berthelot published his book, *La Chimie au Moyen Âge*, in which he cast doubt upon the supposed Arabic origin of many of these mediæval Latin alchemical works, the pendulum immediately swung to the other extreme and appears to have been fixed there ever since.

To those of us who believe that a knowledge of the history of chemistry is not only fascinating in itself, but also an essential factor in the successful development of the science, the lack of information on one of the most fruitful periods of its growth is very disappointing. It is nevertheless true that less than 4 per cent. of the extant Arabic chemical treatises have been published, and that even this small number includes only one work of prime importance. This neglect of Arabic chemistry may be explained by the fact that none of the leading European Arabists has been a chemist, and also in part by the disrepute into which alchemy has fallen. The rich literary treasures of the language of the Qur'ān have left scholars no time for the scientific works, and the chemists seem to have imagined that Arabic chemistry is " alchemy " and therefore more or less unworthy of serious consideration.

Contempt for alchemy is no new thing. It merely represents the confidence felt by the adherents of a particular theory in the superiority of that theory over every other which has preceded it. Thus Lenglet Dufresnoy says, in his *Histoire de la Philosophie Hermétique* (Paris, 1742), " If faut remarquer qu'il y a deux sortes de *Chimie* ; l'une sage, raisonnable, nécessaire même pour tirer des remèdes utiles de tous les êtres de la nature, sans en excepter ni les minéraux ni les métaux ; l'autre est cette Chimie folle et insensée, et cependant la plus ancienne des deux, par le moyen de laquelle les artistes s'imaginent pouvoir convertir les métaux imparfaits en métaux purs et parfaits. La première a conservé le nom de Chimie, et l'on a donné à la seconde celui d'*Alchimie*."

This attitude towards mediæval chemistry dies hard, but it is an attitude which cannot be maintained. We ought not to be blind to the fact that the transmutation theory, the sulphur-mercury theory of metals, and the phlogiston theory denote a very high development of chemical thought, and were in general accord with the observations, experimental data, and philosophical systems of the times in which they were current. Can we say more for any chemical theory of the present day?

The scholars who have studied mediæval Arabic works on chemistry may almost be numbered on the fingers of one hand. If to Berthelot we add Prof. E. Wiedemann of Erlangen, Mr. Robert Steele, Messrs. Stapleton and Azo, and M. Georges Aristarkhes, we shall have a practically complete list of those who have made even tentative excursions into the territory. Of these, Berthelot is the only one who has published complete texts, thirteen of which were printed in tome iii of *La Chimie au Moyen Âge*. Berthelot's pioneer work was extremely useful, and contained a mass of hitherto inaccessible information; but his conclusions were, as usual, hastily drawn and based upon too slender a foundation; they must therefore be accepted with considerable reserve.

It is sometimes stated that the number of Arabic chemical works preserved to us is small, but this is far from the truth. A rough preliminary census of the MSS. in most of the principal libraries of Europe and Cairo has shown that there are at least 300 different treatises extant, including practically all those mentioned by the great Muslim bibliographer, Hājji Khalifa. Some of these works, such as the *Nihāyat aṭ-Ṭalab* of Al-Jildakī, run to a thousand pages, so that the task of arriving at a satisfactory knowledge of the development of chemistry in Islam will be no light one. It becomes obvious that Berthelot's conclusions, based on the study of thirteen small works (occupying altogether only 205 pages), cannot be regarded as authoritative.

It was from the Greeks that the Arabs obtained their early knowledge of chemistry. One of the first Muslims to take an interest in alchemy was Khalid ibn Yazid ibn Mu'awiya (635–704), who was taught the science by a monk named Marianus, in Alexandria, and who had many translations made of Greek alchemical writings. Khalid himself is said to have written many books on the subject, but none of them has come down to us. Several verses and sayings attributed to him are, however, quoted by later authors.

At first, Arabian alchemists seem to have largely contented themselves with studying the translations of Greek books on alchemy, but soon they began to carry out original research, and to write books of their own. These very naturally show the influence of the Greek ideas, but it would be untrue to say (as has been said and often repeated) that the Muslims made no original contributions to chemical science. In the Qur'ān it is written, " *God has made you a middle nation,*" and indeed this central position of the young Muslim empire between Persia and Byzantium on one side, and Egypt on the other, proved extremely valuable for the development of chemistry. The Egyptians excelled in metallurgy and other practical chemical operations, and the combination of this practical side with the habit of chemical speculation derived from the Greeks enabled the Muslims to establish chemistry on the sure ground of a true scientific method.

The best descriptions of Arabian alchemy given by Muslim authorities are to be found in the *Kitāb al-Fihrist*, the *Prolegomena* of Ibn Khaldūn, and the *Kashfu'l-Zunūn* of Hājji Khalifa. The earliest of these three works is the *Kitāb al-Fihrist*, a Muslim encyclopædia written in A.D. 988. In this book there is a section on alchemy containing an account of the supposed origin of the science, its chief exponents and their most important works. According to the author, An-Nadīm, the alchemists his contemporaries claimed a great antiquity for their science, and attributed its origin to Hermes, a ruler over ancient Egypt and a sage and philosopher. He is the *Hermes Trismegistos* of Greek alchemy, and his name is commemorated to this day when we speak of sealing apparatus " hermetically."

Some of the chief alchemists, according to the *Fihrist*, were Moses, Aaron, Pythagoras, Democritus, Plato, Aristotle, Ostanes, Zosimus, Agathodemon, Heraclius, Mary the Copt, Safidus, Khalid ibn Yazid, Jabir ibn Ḥayyan (whose name in its Latin form is famous as *Geber*), Dhu'n-Nūn the Egyptian, Ar-Razi (Rhazes), and Ibn Wahshiyya. It is clear from this list that the influence of Greek thought was very potent in the early days of Arabian alchemy.

Ibn Khaldūn, the greatest philosophical historian of Islam, died in A.D. 1406. In the *Prolegomena* or " Foreword " to his History, he gives a critical account of alchemy, and expresses himself very freely concerning those who used alchemy for such base ends as the manufacture of counterfeit coin. He was, indeed, sceptical of the integrity or intelligence of all those who practised alchemy, and this mental attitude makes his criticism of rather less value than it would have been if he had preserved an entirely open mind.

Our last authority is Hājji Khalifa, a Turkish writer of the seventeenth century. In his great work, *Kashfu'l-Zunūn*, he gives a list of all the Arabic, Persian, and Turkish authors and books known to him, and from it we can glean much valuable information on alchemy. We find that while the old names of power, Khalid and Jabir, are still honoured, they have become almost legendary, and that new masters of the Art have arisen. Hājji Khalifa gives a list of the principal Arabian alchemists and their chief works, and is, indeed, for our purpose, the most useful of the three authorities, as he is the latest and fullest, and gives us a bird's-eye view of the whole range of Arabian alchemy. At least two-thirds of the alchemical books mentioned by him are still extant, although very few have yet been studied by European scholars.

The greatest Arabian alchemist of the early period was Jabir ibn Ḥayyan, who lived in the eighth century A.D., and was reputed to have been a pupil of Khalid ibn Yazid. His fame increased, rather than diminished, with time, and reached the ears of mediæval European scholars, who spelled the name *Geber*. "Geber" was for long considered to have been wonderfully in advance of his age in chemical knowledge, an opinion based upon certain Latin works ascribed to him and alleged to have been translated from the Arabic. But towards the end of the nineteenth century Berthelot had a few Arabic works, supposed to have been written by Jabir ibn Ḥayyan, translated for him into French, and from a study of these translations he came to the conclusion that the Latin works of "Geber" were thirteenth or fourteenth century European forgeries, and that they were not translated from the Arabic at all. Although Berthelot was possibly right, the question can by no means be considered settled, and we must await the results of future research. Of one thing, however, we can be certain: that anyone who is acquainted with the Arabic manuscripts on alchemy cannot fail to recognise in "Geber's" works the same ideas, expressed in almost the same words, as are found in the Arabian alchemists.

The principal alchemists of the later period (A.D. 1100–1400) were Abu'l-Ḥasan 'Alī al-Andalusī, known as Ibn Arfa' Ras (died A.D. 1197), Abu'l-Qāsim Muḥammad ibn Aḥmad al-'Irāqī (thirteenth century), and 'Izz ad-Dīn Aidamir ibn 'Alī ibn Aidamir al-Jildakī (died about A.D. 1360).

The fundamental conception in Greek and consequently in Arabian alchemy is that of the unity of matter. This idea was, however, developed in very many different ways, and subsidiary theories and hypotheses were suggested. The scheme which found most favour with Arabian alchemists involves, as we shall see, the possibility of the transmutation of the metals as a necessary consequence. It cannot be too often repeated that the chemical system of the Muslims was a logical system, in accord with the experimental work of the time, and limited only by that experimental work, as all theories must be limited by the practical experience of the period in which they are current.

It was believed by the Muslim chemists, using Aristotelian notation, that the *Prime Matter* of the universe, before it can become a definite substance, must be united with *Specific Form*, and according to the specific form which it receives the prime matter gives rise to all the various substances of which the universe is composed. The most elementary kinds of specific form are those which, united to the Prime Matter, give rise to Fire, Air, Water, and Earth, the "Four Elements" of Aristotelian philosophy. Each of the Four Elements has qualities which distinguish it from the others; thus, fire is hot and dry, air is hot and moist, water is moist and cold, earth is cold and dry. Any one Element may pass directly into another with which it has one property in common, by means of that property; thus, if air is heated it becomes fire, and if water is cooled it becomes earth. It is clear, therefore, that the Four Elements in one way resemble our three "physical states," with the addition of the state of incandescence.

All substances are composed of the Four Elements in varying proportions and different combinations, but the Prime Matter is the same in all. By changing the Specific Form, transmutation of one substance into another is therefore possible: the first stage in such a change is called "Corruption," which means that the original specific form is lost, and the second, which follows immediately, is called "Generation," and implies that the Prime Matter takes on another Specific Form.

The three main classes of compound substances are Vegetable, Mineral, and Animal, but these are again divided into many species. One of the species of Minerals is the Metallic. All metals are therefore *one in species*, *i.e.* they are composed (like all other substances) of the Prime Matter, united with the *same Specific Form*. If this is so, how are we to account for the existence of seven different metals, gold, silver, copper, lead, tin, iron, and mercury? The theory of the Arabian alchemists was that the perfect state of the metallic species is represented by gold. Other metals have failed to reach the state of perfection, owing to the presence in them of certain *accidental* qualities, that is, qualities which are not essential to the metallic species and which may be removed by proper treatment. " Imperfect " metals are often compared to a man suffering from illness : if the illness be removed by administration of an appropriate drug, or in some other way, the sick man returns to his normal state of health.

The possibility of the transmutation of the metals is logically required by this theory, and it is interesting to remember that we have reached very much the same position in chemical theory to-day. The difference is, of course, that we have an incomparably fuller knowledge of the structure of matter than the mediæval chemists had, and believe that no ordinary chemical reaction can ever bring about appreciable transmutation. But it is difficult to imagine what other theory could have inspired chemistry and encouraged chemical research in the early Middle Ages so much as that of the Transmutation of the Metals. It will be seen, too, that this theory was not the fundamental theory of chemistry : it has acquired that reputation solely because it represented the most important and practical problem of chemistry that the alchemists set themselves. The possibility of transmutation was by no means universally believed in by mediæval Arabian chemists. Avicenna vehemently opposed it, and we find many criticisms of it quoted by both Ibn Khaldūn and Hājji Khalifa. These criticisms no doubt proved a useful spur to further experimental work and modifications of theory. But had they been accepted and the theory of transmutation abandoned, it is probable that the development of chemistry would have been greatly retarded.

The details of the methods employed to perfect " imperfect " metals vary considerably from time to time, and from chemist to chemist, but the general feeling appears to be as follows.

Fire alone may possibly be sufficient, but there are practical difficulties to be overcome, and these prove to be insurmountable. The alternative is to prepare a substance which, in our modern phrase, will act as a catalyst on the reaction, or which will restore the balance of the imperfectly adjusted metal and so bring it to perfection—hence alchemy is sometimes called the " science of the Balance " : the name must not be taken as referring to a machine for weighing, although the alchemists were as a rule very careful to insist upon accurate weighing.

Gold was considered to be in a state of perfect equilibrium, while the other metals differed from it by excess or deficiency of certain constituents. The problem then was to find a substance which would remove the excess or make up the deficiency, and this substance was called the Elixir (*Al-Iksīr*) or the Philosopher's Stone. It was usually thought that no one substance would be sufficient: there must be two Elixirs, a red one to convert silver into gold and a white one to convert the remaining metals into silver. Thus, to convert copper into gold it must first be converted into silver by the White Elixir, and then the silver into gold by the Red Elixir. All the alchemists were agreed that a minute portion of the Elixir would convert an unlimited amount of an imperfect metal into gold; Mary the Copt, for example, is quoted as saying "One *dirham* thereof is sufficient for all that lies between the East and the West." For this conception to have arisen, some idea of catalytic action must have been arrived at; or it may have originated from the observation of the effect of a small piece of yeast upon a large mass of dough.

The different stages in the process of transmutation can usually be made to agree with the following scheme:

(i) Preparation of the materials.

(ii) Mixing together by pounding.

(iii) "Putrefaction" or coction at a gentle heat in the dark, in the presence of moisture. At this stage the substance is black.

(iv) Albification, when the substance goes white.

(v) Rubification, when the colour changes to red and the Elixir is formed.

(vi) Fixation, to preserve the strength of the Elixir.

(vii) "Projection" of a small portion of the Elixir upon a fused mass of metal in the crucible.

(viii) "Catalytic" effect of the Elixir upon the metal.

(ix) Transmutation.

If in (vii) the Elixir is projected upon Mercury, the latter is converted not into gold but into more Elixir. If stage (v) be omitted, the product is the White Elixir.

The following little poem is taken from a manuscript of a work, ascribed to Jabir ibn Ḥayyan, preserved in the Bibliothèque Nationale, Paris (Arabe 2625, foll. $57^v$–$58^r$).

An Ode from the "Book of Properties" (by *Jabir ibn Ḥayyan*), on the Elixir, with a commentary.

1. When the sun is in Aries and the season good and equable
2. Take calcined shells, pure in colour, and thin plants from the mountain
3. And sal-ammoniac, which has no equal; choose the white for your work.
4. Three parts make complete, with true measure, without deviation.
5. Then powder them well, so that they become like clay when it is kneaded,
6. And dissolve them if you wish to reach to the perfected knowledge of the philosophers.
7. They will give a liquid beautiful in appearance, red as blood when it flows.
8. With this liquid moisten pure gold and carefully chosen cinnabar.

9. And melt them to a wax with a light fire. (You will attain your desires and your hopes.)
10. Do this three times, and be wise—the way to perfection is clear.
11. To the product add pure quicksilver, if you desire success, and pour out the measure,
12. Then plunge it repeatedly into the blaze, and do not be like an ignorant man in doing so.
13. You will see it now as a saffron-yellow earth, delighting souls by the beauty of its excellence.
14. With it you can tincture [other metals] into pure gold; therefore be grateful to Him who supports the Heaven
15. And glory to Him, the Giver, the Provider, Generous in giving to him who asks.
16. And fear not the vicissitudes of Time, for thou art but temporal and in Time didst originate.
17. And thou wilt attain what kings attain not. If thou seekest it, here is the goal.

And this is the explanation of the Ode, and how to carry out the operation thereby, if Allah will:

Take one part of calcined shell and one part of washed, cut, and soft human hair, and one part of white sal-ammoniac; let the three be well mixed by powdering on a flat stone until they become like clay, and let them be dissolved in the dissolving vessel familiar to scientists. Verily, they will be dissolved to a deep red water which would dye when hot, or on rubbing, except for the fact that it does not permeate. Then take an ounce of good cinnabar and a *mithqal* of gold leaf, powder the cinnabar and the gold above-mentioned, moisten them with the solution, and place them in a "waxing" vessel (the joints of which have been securely closed) upon moderately warm ashes. If the vessel above gets too hot, remove it from the fire to get cool. Powder the product and moisten it in this way three times, and do not open the vessel until it is cold, so that the colouring spirits may not fly away from it. And when you have moistened it thus three times, take it out and powder it well, and add to it an equal measure of well-washed mercury. The mercury will be drunk up by the powder. Then place the substance in the "burial apparatus" [this usually means a hole in a rock, where the substance may cool well, and deliquesce if it be a deliquescent substance], and leave it for a night under the vault of heaven. You will then see that your product has become a homogeneous substance in which there is no trace of the "slave" [a common alchemical term; it probably means mercury, but I am not quite sure of this]. It is now a yellow earth; preserve it, for if you project one part of it upon 45 [of silver or other metal] it will turn them into pure gold.

I have given this little work in full because it shows us very clearly the kind of chemical phenomenon which appeared to the alchemists to support their theory of transmutation. The process above described (which is obviously based on experimental work and observation) would result in an impure amalgam of gold, mixed with metallic sulphides and other things; the fusion of this with silver would result in a gold-silver alloy, of a yellow colour and therefore resembling gold; for which it might easily be mistaken.

The importance of accurate *weighing* was insisted upon by most Muslim alchemists, though the exact form of balance they used is not described in any of the manuscripts which I have read. Al-Khazini's hydrostatic balance and the determinations of specific gravity he carried out therewith have been described by Bolton. Al-Khazini himself says, "The advantages of the hydrostatic balance are (1) exactness in weighing; this balance shows variations to the extent of a *mithqal* [a small weight], although the entire weight be a thousand *mithqals*, provided the maker has a delicate hand, attends to the minute details of the mechanism, and understands it; (2) that it distinguishes pure metal from its counterfeit, each being recognised by itself without any refining; (3) that it enables one to know the constituents of a metallic body without their separation from one another; (4) that it shows the superiority in weight of one of two metals over the other in water, when their weight in air is the same, and conversely; (5) that it makes the substance of the thing weighed to be known by its weight."

The table of weights commonly employed was:

| | | | | |
|---|---|---|---|---|
| 2 | qirats | = | 1 | daniq |
| 6 | daniqs | = | 1 | dirham |
| 7 | mithqals | = | 10 | dirhams |
| $10\frac{2}{3}$ | dirhams | = | 1 | ounce |
| 12 | ounces | = | 1 | ratl (= about 1 lb. avoirdupois) |

Another table is:

| | | | | |
|---|---|---|---|---|
| $8\frac{2}{5}$ | habbas | = | 1 | daniq |
| 6 | daniqs | = | 1 | dirham |
| $1\frac{3}{7}$ | dirhams | = | 1 | mithqal |
| $4\frac{1}{2}$ | mithqals | = | 1 | istar |
| $1\frac{2}{3}$ | istars | = | 1 | ounce |
| 12 | ounces | = | 1 | ratl |

(This is even more complicated than the English system!) Change of weight during a chemical reaction was not observed, or at least was not considered to be of much importance.

Apparatus.—Abu Bekr ibn Zakariyya ar-Razi (died about A.D. 900) gives a list of apparatus necessary for the practice of alchemy, of which the following items are typical:

(1) Furnace.
(2) Bellows.
(3) Large crucible.
(4) Smaller crucible.
(5) Ladle.
(6) Shears.
(7) Pestle.
(8) Cauldron.

(9) Alembic.
(10) Receiver.
(11) Retorts.
(12) Aludel.
(13) Ovens.
(14) Glass basins.
(15) Flasks.
(16) Flat stone for pounding.
(17) Roller for same.
(18) Stove.

## LIST OF AUTHORITIES

BERTHELOT, *La Chimie au Moyen Âge*, 3 vols., Paris, 1893.
STAPLETON, *Memoirs of Royal Asiatic Society of Bengal*, 1905.
KOPP, *Beiträge zur Geschichte der Chemie*, 1875.
HERBELOT, *Bibliothèque Orientale*, 1697.
LECLERC, *Histoire de la Médecine Arabe*, 2 vols., Paris, 1876.
WIEDEMANN, various papers in *Z.D.M.G.* and elsewhere.
AN-NADĪM, *Kitab al-Fihrist*, ed. Fluegel.
HĀJJI KHALIFA, *Kashfu'l-Zunun*, 2 vols.
AL-'IRĀQĪ, *Al-'ilm al-muktasab fi zira'at adh-dhahab* (MS.).
AL-JILDAKĪ, *Nihayat at-Talab* (MS.).
IBN ARFA' RAS, *Shudhūr adh-dhahab* (MS.).

# SOME FACTORS IN THE LIFE-HISTORY OF THE LEUCOCYTE

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A MICROSCOPIC examination of fresh normal human blood reveals the fact that it consists of a colourless fluid part, the blood-plasma, in which are suspended enormous numbers of non-nucleated circular biconcave discs, the red blood corpuscles or erythrocytes, and a much smaller number of nucleated more or less amœboid cells, the white blood corpuscles or leucocytes. The much smaller blood platelets are usually undiscernible by this method of examination.

In health, whilst the erythrocytes are all uniform in character and appearance, the leucocytes, on the other hand, show many differences among themselves. Thus they vary in size, in the size and shape of the nucleus, and in the amount and appearance of the cytoplasm, which may be hyaline or finely or coarsely granular. Hence several varieties can readily be distinguished and recognised.

It is, however, chiefly upon stained preparations of blood films that we rely for the recognition and accurate differentiation of the various kinds of leucocytes. A great advance in the study of the morphology and functions of these cells was made by Ehrlich when he applied to them special methods of fixation and staining, chief amongst which was the employment of his triacid stain. The discovery of the Romanowski double stain and its more recent modifications in Jenner's, Giemsa's, and Leishman's stains have added greatly to our knowledge of this subject, and to the ease and accuracy with which the various types of leucocyte can be recognised.

To prepare stained blood films after this method one may proceed as follows: After cleansing the skin of the finger or of the lobe of the ear with ether, the specimen of blood is obtained by sharply pricking the skin in the cleansed area with a Hagedorn needle sterilised by passing through the flame of a Bunsen burner or spirit lamp. The drop of blood so obtained is placed on a clean slide, and a uniform film is made by spreading it with another clean slide pushed along at an angle of 45 degrees. The film thus obtained is allowed to dry in the air and may then be stained with any appropriate stain, such as Jenner, Giemsa, Leishman, or Ehrlich's triacid stain. I have almost entirely employed Leishman's stain, the staining being thus carried out: the air-dried film is flooded with Leishman's stain, two minutes later double the amount of distilled water is added, and after thorough mixing is allowed to stand for a further period of eight minutes. During this process care should be taken that the slide is not allowed to dry. The film is then thoroughly washed in distilled water and allowed to dry in the air. Microscopic examination is then carried out, using a $\frac{1}{12}$-inch oil-immersion lens. To facilitate counting, and to avoid counting the same field twice over, a movable stage should be used.

By this method of staining the granules present in some forms of leucocyte are brought into great prominence. From the appearances thus presented Ehrlich classified the leucocytes according to the affinity of their granules for aniline dyes into (*a*) Acidophile, which stain readily with acid dyes such as eosin; (*b*) Basophile, which stain readily with basic dyes such as methylene blue; and (*c*) Neutrophile, which stain only with a mixture of acid and basic dyes.

According to Ehrlich's conception an acid dye is usually a salt in which the part of an acid radicle is played by the coloured substance. Thus, for example, the acid dye eosin is the sodium salt of tetrabromfluorescin, which is a coloured acid. A basic dye, on the other hand, is usually a salt with a basic colour radicle. Thus methylene blue is the chloride of tetramethyldiphenthiazine, which is a coloured base. The conventionally termed "neutral" dyes consist of a coloured base loosely combined with a coloured acid as in the so-called "eosinate of methylene blue."

In addition to the presence or absence of granules and the number and affinity of the granules for dyestuffs, other factors are employed in the classification of the leucocytes, namely the size of the cell and the shape, size, and tenuity of the nuelcus.

Classified on this basis, normal human blood contains the following varieties of leucocyte, together with the percentages they form of the total number of leucocytes:

1. Lymphocytes, large and small (22 per cent.).
2. Polymorphonuclear neutrophilous leucocytes (70 per cent.).
3. Large hyaline mononuclear leucocytes (4 per cent.).
4. Transitional leucocytes (1 per cent.).
5. Eosinophilous leucocytes (2·5 per cent.).
6. Basophilous leucocytes or "mast-cells" (0·5 per cent.).

In certain pathological states there may be an increase or decrease, relative or absolute, of any or all of these varieties of leucocyte, whilst the blood may also contain abnormal forms of white cells constituting the various types of myelocyer developed from the bone marrow.

In the present communication it is with only two of these varieties of leucocyte that I propose to deal, incorporating therein some recent personal observations. These two varieties are the polymorphonuclear neutrophilous leucocyte and the large hyaline mononuclear leucocyte respectively.

*Polymorphonuclear Neutrophilous Leucocytes.*—Of the various types of leucocyte present in normal human blood, the polymorphonuclear neutrophilous leucocyte is the most abundant. From 70 to 75 per cent. of all the leucocytes are of this variety. In the various leucocytoses this number is greatly increased, reaching 90 per cent. or upwards. It is an actively phagocytic body, and on this account was termed "microphage" by Metchnikoff. By the production of a ferment-like body "microcytase," it digests and destroys bacteria and other substances which have been phacocytosed.

The most striking microscopic characteristic of this variety of leucocyte is provided by the appearance of the nucleus which, though always single, often appears to be multiple, on account of the amount and character of the segmentation or fragmentation which it presents. It is to this characteristic that the designation polymorphonuclear, or as commonly abbreviated polymorph, applied to these structures, is due.

These nuclear segments vary greatly in number and may present a great variety of shapes, being round, oval, looped, S-shaped, Z-shaped, or quite irregular.

In 1904 Arneth drew attention to the arrangement of the nuclear segments of the polymorphonuclear leucocytes, and pointed out that it was uniformly constant in normal blood, and suggested that it should be employed as a basis for the classification of these cells, and that a differential enumeration of them could thus be made. Arneth made his classification very elaborate, making use not only of the number, but also of the shape, of the nuclear segments, together with their arrangement. Without following Arneth into all the elaboration and complexity of his classification, a sufficiently accurate and comprehensive differential polymorphonuclear blood picture may be obtained by classifying these cells according merely to the number of the definite segments of the nucleus without reference to their shape, size, or arrangement. This method gives five classes as follows: Class I comprises cells with unipartite or undivided nucleus; Class II cells with bipartite nucleus, having two segments; Class III with tripartite nucleus, having three segments; Class IV with quadripartite nucleus, having four segments; and Class V with multipartite nucleus, having five or more segments.

In health and under normal conditions, segmental neutrophile blood picture is remarkably constant, giving very little variation from the numbers given by Arneth, as shown in Table I, which constitutes the normal:

TABLE I.—SHOWING NORMAL ARNETH'S COUNT

| — | Class I. | II. | III. | IV. | V. |
|---|---|---|---|---|---|
| Number of segments in percentages | 5 | 35 | 41 | 17 | 2 |

In pathological conditions, on the other hand, especially when associated with toxæmia, this relationship is altered, the amount of alteration being proportional to the toxæmia present. This alteration consists in a diminution of the more segmented forms, so that a relative increase of Classes I and II results. This condition Arneth speaks of as "lævodeviation," or "dislocation to the left." This lævodeviation in various diseases is readily seen in Table II.

TABLE II.—SHOWING LÆVODEVIATION IN VARIOUS DISEASES

| — | Class I. | II. | III. | IV. | V. |
|---|---|---|---|---|---|
| Normal percentage | 5 | 35 | 41 | 17 | 2 |
| Typhoid fever | 43 | 36 | 16 | 5 | 0 |
| Scarlet fever | 26 | 35 | 30 | 8 | 1 |
| Measles | 50 | 35 | 14 | 1 | 0 |
| Erysipelas | 47 | 35 | 19 | 1 | 0 |
| Diphtheria | 21 | 48 | 25 | 5 | 1 |
| Whooping-cough | 27 | 39 | 31 | 3 | 0 |
| Chicken-pox | 33 | 35 | 28 | 4 | 0 |
| Empyema | 35 | 33 | 25 | 7 | 0 |
| Oral sepsis | 26 | 38 | 30 | 6 | 0 |

It is in connection with pulmonary tuberculosis that I have specially observed this condition. In a series of cases of pulmonary tuberculosis in which, in collaboration with Dr. Horace Wilson, I have investigated the condition of the leucocytes after Arneth's method, very interesting results were obtained.

In one series where phthisis was merely suspected, the counts were normal, showing no deviation, and none of these patients developed the disease. In another series, where the patients all died at no very distant date after making the blood counts, well-marked lævodeviation was observed in every case. In cases still living, but all doing badly, as the remarks of the present condition given herewith show, the amount of lævodeviation present may be seen from the following table (Table III):

TABLE III.—SHOWING LÆVODEVIATION IN PULMONARY TUBERCULOSIS

| No. | — | Class I. | II. | III. | IV. | V. | Remarks. |
|---|---|---|---|---|---|---|---|
| | Normal | **5** | **35** | **41** | **17** | **2** | |
| 1 | M | 18 | 64 | 17 | 1 | 0 | Chronic fibrosis, stationary. |
| 2 | F | 18 | 46 | 22 | 10 | 4 | Early phthisis, genito-urinary tuberculosis. |
| 3 | M | 31 | 57 | 10 | 2 | 0 | Fibrosis, improving. |
| 4 | M | 16 | 45 | 32 | 4 | 3 | Chronic, doing badly. |
| 5 | M | 21 | 47 | 29 | 2 | 1 | Chronic, doing badly. |
| 6 | M | 17 | 46 | 34 | 2 | 1 | Doing badly. |

Now, Arneth considers that toxæmias bring about the destruction of neutrophile leucocytes, the disintegration affecting particularly the older cells, so that forms possessing the most divided nucleus disappear first from the blood. Hence the neutrophile blood picture may be taken as an index of the severity of the intoxication.

That toxic substances circulating in the blood actually do bring about the destruction of the neutrophile leucocytes is proved by examination of the blood in cases of poisoning by Tri-nitro-toluol and allied substances. Cases of Tri-nitro-toluol poisoning occurred not infrequently in certain classes of munition workers during the Great War, especially among "T.N.T. Fillers." In one fatal case in which I made a differential leucocyte count shortly before death, the destruction of the polymorphonuclears was carried to such an extreme degree that none of the well-known varieties of leucocyte could be detected, such leucocytes as were present consisting entirely of badly staining degenerate-looking cells, somewhat resembling abnormal lymphocytes. This condition of the leucocytes produced a striking picture of the histological appearances of the blood—a peculiarity which I have never encountered in any other condition. These findings are quoted to support Arneth's views that toxæmic conditions bring about destruction of the polymorphonuclear leucocytes, but the destructive process had here been carried to such a degree that all the five varieties had disappeared alike, leaving open the question whether there was any difference in the order of their destruction.

If this explanation of Arneth be correct, it appeared to me that it may be assumed that the general functional activity of the neutrophile leucocyte will vary with the age, and therefore with the amount of nuclear segmentation presented by these cells, and that the measure of their functional activity may be obtained by ascertaining the phagocytic power of the various classes of leucocyte when placed in the same environment and subjected to the same dosage of opsonin.

In a series of 42 opsonic index determinations for the *Staphylococcus pyogenes aureus*, in which 4,183 polymorphonuclear leucocytes and 6,340 micro-organisms were enumerated, I have taken the phagocytic activity of the leucocytes as an index of their functional activity, the results being shown in the accompanying table (Table IV), and graphically in the accompanying chart (Chart I).

TABLE IV.—NUMBER OF LEUCOCYTES AND INGESTED COCCI IN 42 OPSONIC INDEX DETERMINATIONS

| Nuclear Segments of Leucocytes. | Class I. | II. | III. | IV. | V. |
|---|---|---|---|---|---|
| Cocci | 569 | 2,744 | 2,321 | 625 | 81 |
| Leucocytes | 409 | 1,758 | 1,531 | 425 | 60 |
| Average number of cocci per cell | 1·39 | 1·62 | 1·51 | 1·47 | 1·35 |

The table and chart (Chart I) clearly show that the neutrophile leucocyte of Class I with undivided nucleus possesses a moderate power of phagocytosis (1·39), that this power of phagocytosis reaches its maximum in leucocytes with bipartite nucleus in Class II (1·62), and then progressively diminishes

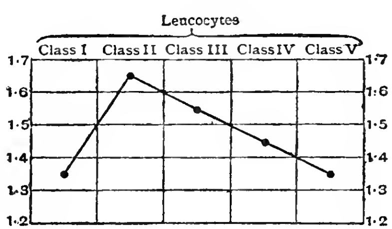


CHART I.—Showing average number of cocci ingested by leucocytes according to number of nuclear segments.

The decimal figures given on each side of the chart indicate the number of cocci injected per leucocyte.

through Class III (1·51) and Class IV (1·47) as nuclear division increases, being lowest in Class V (1·35).

Again, in cases where tuberculin was administered, it was observed that those showing lævodeviation lived longer than those with similar counts where tuberculin had not been administered. This observation would appear to suggest that the administration of tuberculin counteracts to some extent the effects of the toxæmia present.

The analysis of the cases investigated by this method thus brought out some striking results, investing Arneth's leucocyte count with a usefulness in the diagnosis and prognosis of pulmonary tuberculosis hitherto insufficiently recognised.

The behaviour of the nuclei of the leucocytes to the effects of toxæmias in the production of lævodeviation is explained by Arneth on the views which he holds on the origin, development, and life-cycle of these cells. According to his hypothesis the neutrophile leucocytes are developed from the myelocytes of the bone marrow. At their origin they possess an undivided nucleus. Later the nucleus divides and continues to divide so that the nuclear segmentation becomes greater with increasing age. Hence cells of Class I with unsegmented nuclei are the youngest. As they increase in age or with progressive segmentation Class I gives place to Class II, and this again to Class III, and so on, so that cells of Class V present the oldest individuals where nuclear segmentation reaches its maximum.

It would therefore appear that by taking phagocytic power as an indication of functional activity, and this again as an indication of the age of the cell, the neutrophile leucocytes with undivided nuclei are young and immature, those with bipartite nuclei being endowed with full functional activity and power have reached adult life, and that thereafter progressively increasing nuclear division indicates increasing age and diminished functional activities.

These results, whilst they may be taken as in some measure supporting the views put forth by Arneth on the relationship between the age and functional power of the neutrophile leucocyte and their behaviour in the various toxæmic conditions present in disease, have also made a considerable addition to our knowledge of the functions and life-history of these cells.

It has long been known that an increase in the total number of leucocytes in the blood occurs in the condition known as leucocytosis, and that most commonly this leucocytosis is due to an increase in the number of polymorphonuclears present, the number of the other varieties remaining unchanged. An increase in the relative percentage of polymorphonuclears thus results. This total increase in the number of leucocytes, together with an increased relative percentage of polymorphonuclears, is met with in every sort of acute inflammatory process. Thus in acute septic infections, in pneumonia, in erysipelas, in endocarditis, etc., the leucocyte count may rise to 60,000 per c.mm., or even more, the polymorphonuclears giving a relative percentage of 90 to 95.

Certain chemical substances like nucleic acid and yeast also produce a polymorphonuclear leucocytosis, and this fact has been made use of therapeutically where an increase in the number of these cells seemed desirable. An increase in the amount of phagocytosis can thus be secured, and by obtaining increased phagocytosis, increased destruction of micro-organisms can be brought about. Not only may increased phagocytosis be procured by increasing the number of phagocytic leucocytes, but also by increasing the opsonic content of the body fluids, and by increasing the phagocytic activity of the leucocytes themselves. Tunnicliffe has recently shown that the phagocytic activity of the polymorphonuclear leucocytes can be stimulated both *in vivo* and *in vitro* by the newer organic compounds of arsenic such as neoarsphenamin and neosalvarsan in proper concentrations (1 in 100,000). *In vivo* this result is very rapidly obtained, as a rule, within thirty minutes after intravenous injection. Whether this stimulation of the phagocytic activity of the polymorphonuclear leucocytes by the administration of neoarsphenamin and neosalvarsan is of significance in the therapeutic action of these drugs remains for further research to determine.

*Large Hyaline Mononuclear Leucocytes.*—These are the largest cells present in normal blood, being about two or three times the diameter of the red blood corpuscle. In them the cytoplasm is relatively more abundant than in the lymphocytes. It stains very faintly with aniline dyes, and being hyaline in appearance is devoid of granules. The nucleus is large and may be round, oval, indented, reniform, or twisted. It stains less intensely than that of the lymphocyte, which this cell somewhat resembles. The nucleus further is usually excentric in position, being near the margin of the cell. The large hyaline mononuclear leucocytes are present in small numbers in normal blood, constituting about 4 per cent. of the total number of leucocytes.

Along with the typical large hyaline mononuclears are usually enumerated the " transitional " leucocytes, which may be considered to be atypical large hyalines since they possess characters intermediate between those of the true large hyalines and polymorphonuclear neutrophile leucocytes.

A relative increase and the number of large hyaline mononuclears and transitionals is characteristic of protozoal infection. It is almost constantly found in such protozoal infections as malaria, syphilis, yaws, kala-azar, and the trypanosomiases.

Another condition in which a relative large hyaline leucocytosis occurs—as has been recently shown by Browning—is sympathetic ophthalmia (*Irido-cyclitis sympathica*). This is a condition much dreaded by the ophthalmic surgeon. It is characterised by the occurrence of a plastic inflammation of the ciliary body leading to loss of vision in an eye, following receipt of a perforating injury in the opposite eye, which itself becomes the seat of a plastic inflammation in the ciliary body.

It is therefore particularly liable to follow after operative procedure, whilst the presence of a foreign body particularly favours the onset of this condition. Hence the grave danger constituted by the presence of a foreign body in the eye. The position of the injury is also of importance in this connection. A perforation of the globe in the region of the ciliary body is most liable to be followed by sympathetic ophthalmia in the opposite eye, and this liability is greatly enhanced where the ciliary body prolapses in the wound. Usually a period of a few weeks must elapse before the sympathetic ophthalmia develops, but it may then occur at any subsequent period, having been observed as long as forty years after the receipt of the injury in the first eye. Hence, an eye which has once been destroyed by injury remains for the rest of life a menace to the other eye.

The relationship of infection to this disease, and the powers of transmission of the disease from the injured to the sound eye, have not yet been definitely determined. Where, on the one hand, the perforating injury and its sequelæ run a perfectly aseptic course, and, on the other hand, when frank suppuration occurs sympathetic inflammation does not result. Animal experimentation has failed to shed any light on the transmission of this disease, since it never occurs spontaneously in animals, and no attempts to produce it experimentally in animals have been successful. Hence the importance of Browning's discovery of the large hyaline leucocytosis associated with sympathetic ophthalmia. The following differential counts which I have obtained in some cases of sympathetic ophthalmia fully confirm Browning's observation (Table V).

TABLE V.—SHOWING THE LARGE HYALINE LEUCOCYTOSIS IN SYMPATHETIC OPHTHALMIA

| No. of Case: | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|
| Polymorphonuclears | 69 | 62 | 47 | 63 | 66 | 51 | 57 |
| Lymphocytes | 10 | 24 | 30 | 22 | 11 | 24 | 23 |
| Large hyaline mononuclears and transitionals | **17** | **12** | **18** | **13** | **19** | **21** | **14** |
| Eosinophiles | 2 | 1 | 4 | 2 | 4 | 4 | 5 |
| Basophiles | 1 | 1 | 1 | 0 | 0 | 0 | 1 |

The value of intravenous injections of the organic compounds of arsenic such as salvarsan and its substitutes has long been known in certain protozoal infections. The similarity of the blood picture in sympathetic ophthalmia and in protozoal infections led Browning to suggest that cases of sympathetic ophthalmia should also be treated in this way. Strikingly beneficial results have been obtained by this method of treatment in cases of sympathetic ophthalmia, with restoration of the blood picture to the normal—a result which constitutes one of the greatest advances made in ophthalmic therapeutics in recent years.

Another disease, again, in which a relative large hyaline mononuclear leucocytosis is usually stated to be present is variola or smallpox, and this fact may add some weight to the view that it is to the protozoa rather than to the bacteria proper that we must eventually look for the causal microorganism of the disease.

In making differential leucocyte counts it was shown by Lucey that the percentage of large hyaline mononuclears tends to vary according to the seat of origin of the drop of blood taken for examination, and the method observed in spreading the film. When, for example, blood is obtained by puncture of the lobule of the ear, and the first or second drop obtained is used for making the film, a much larger mononuclear leucocytosis is found even in normal individuals than when blood is obtained direct from veins, or by pricking a finger. If, however, the ear be warmed, rubbed, or massaged before making a puncture, and the first and second drops are discarded, this false leucocytosis is not observed. Similarly, excessive squeezing of the tissues should be avoided as this tends to raise the relative lymphocyte, but not the larger hyaline, count. Lucey attributes these findings to the concentration of the large hyaline leucocytes in the capillaries of the ear, such concentration being due to the slowing down of the circulation in this situation. Owing to the immobility of this organ, to the absence of muscular movements, and to its exposed position to cold, retardation of the circulation is particularly liable to occur in the lobule of the ear, which therefore should be avoided in obtaining blood for differential leucocyte counts, unless the precautions enumerated above are strictly observed.

The consideration of the two varieties of leucocytes dealt with in this communication by no means exhausts the possibilities of the differential count. The remaining white blood cells—namely, the lymphocytes large and small, the eosinophiles and the basophiles, as well as the abnormal forms of leucocyte found in various blood diseases—all provide interesting subjects for study and investigation.

The factors concerned in the life-histories of the various leucocytes here considered have been drawn exclusively from human sources. So far as I am aware but little work has been done in this field with respect to animals either in health or disease, and equally important and interesting results would appear to await the worker who is prepared to apply similar methods to the critical observation and differentiation of the different varieties of leucocyte which are found both in normal and in various pathological conditions to be present in the blood of the remaining members of the animal kingdom.

## REFERENCES


1. Arneth, J., "Die Neutrophilen Leukozyten bei Infektionskrankheiten," *Deutsch. Med. Wochenschr.*, 1904, vol. xxx, pp. 54 and 92.
2. Browning, S. H., "The Use of Salvarsan in Ophthalmic Practice," *Proc. Roy. Soc. Med.* (*Ophthalm. Sect.*), 1914, p. 88.
3. Cooke, W. E., "The Nucleus of the Neutrophil Polymorphonuclear Leucocyte in Health and Disease," *Journ. Path. and Bacteriol.*, 1914–15, vol. xix, p. 494.
4. Gregorson, A. W., and Taylor, F. E., "On Trinitrotoluene Poisoning, with Records of Five Cases," *Glasg. Med. Journ.*, August 1918.
5. Lucey, H. C., "Observations Bearing on the Reliability of the Large Mononuclear Leucocyte Count as an Aid to the Diagnosis of Malaria," *Proc. Roy. Soc. Med.* (*Sect. Trop. Dis. and Parasit.*), 1921, vol. xiv, p. 53.
6. Newham, H. B., and Duncan, J. T., "A Note on the Arneth Count in Malaria and Dysentery," *Journ. Trop. Med. and Hyg.*, 1921, vol. xxiv, p. 301.
7. Taylor, F. E., "The Relationship between Nuclear Division and Phagocytic Power in Polymorphonuclear Leucocytes," *Lancet*, July 1915.
8. Taylor, F. E., "Nuclear Segmentation of Neutrophile Leucocytes in Health and Disease," *The Practitioner*, 1915, vol. xcv, p. 503.
9. Taylor, F. E., and Wilson, H., "The Value of Arneth's Leucocyte Count in Pulmonary Tuberculosis," *Brit. Journ. Tuber.*, July 1917.
10. Tunnicliffe, R., "The Action of Neoarsphenamin and Neosalvarsan on the Phagocytic Activity of Leucocytes," *Journ. Inf. Diseases*, 1922, vol. xxx, No. 5, p. 545.

# POPULAR SCIENCE

## LUNAR PERIODICITY IN LIVING ORGANISMS

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A SUPPOSED influence of the moon on plants, animals, and on the affairs of men is found mixed with the religious ideas of nearly all primitive peoples. It persists to-day in folklore and superstition. Most of us have turned a coin in our pockets for luck on first seeing the new crescent, wishing that with the growing moon the money and our general prosperity might too be increased. This in reality is the key to the origin of most moon beliefs. The moon is one of the most striking of natural objects seen by primitive man, and one which varies most in aspect. By association of ideas the moon's increase and decrease is then supposed to influence the increase and decrease of any changing process.

This assumption has left its trace in the superstitions of many present-day peasants in Europe and elsewhere, who believe that hair, nails, corns, etc., cut under a waxing moon grow again more quickly than when cut under a waning moon, and that sickness disappears most rapidly when treated under a waning moon. The same ideas were current in ancient Rome, for Pliny says that Tiberius "for hair-cutting observed the increasing phases." Hence sheep are shorn under a waxing moon, and to-day in Greece the peasants arrange that lambing and calving shall take place in the growing phases. The same belief can be traced into nearly all departments of human activity. Thus in parts of Africa to-day war, journeys, or business must be commenced with a waxing moon if they are to be successful, and the same is related by Cæsar (*De Bello Gallico*) and Tacitus (*Germania*) of the ancient Germans. Marriages, too, must take place during the first half of the lunar month.

From this idea it is but a short step to associate the waxing and waning moon with the growth and decay of vegetation.

The belief is found already in the Zend-Avesta and again in a number of Greek and Roman authors. Connected with the same notion is the conception of the moon as a source of moisture and thus an aid to plant growth. Plutarch says that "dew falls most at full moon," and in another place, when speaking of Osiris as a moon-god, refers to "his humid and generative light favourable to the growth of plants." The same function was ascribed to the Greek Artemis.

The supposed rôle of the moon as a source of moisture seems to derive from the fact that there is most radiation from the ground and hence the greatest deposit of dew on cloudless nights. The moon has no effect on the cloudiness or otherwise of the sky—meteorologists are decided on this point, in spite of the saying of sailors that "the moon eats up the clouds"—but it is on cloudless nights only that the moon is visible, and it is just on these nights that dew is formed. Thus the dew is credited to the moon. So gardeners fear the April moon, for at this season excessive radiation injures young shoots by reducing their temperature unduly. This occurs on cloudless nights, which are most noticeable when there is a moon to light the sky.

There is an ancient belief and one that is widespread to-day that sowing and planting must be done under a waxing, reaping and cutting under a waning moon. Presumably the crops are supposed to be increased like many other things by the growing moon. The idea lying behind harvesting or felling timber beneath a waning moon is more difficult to trace, but may be connected with the drying influence which is ascribed to the declining phases in the same way as dew is attributed to the waxing and full moon. At all events the belief is most widespread that wood for building purposes is not durable unless cut after the full moon, and indeed until the Revolution French law ordained that trees should be felled only under a waning moon. In Trinidad, where the belief is strongly held, experiments were recently made which demonstrated the absence of any basis of truth to the superstition.

Passing now to animals, it is principally on marine invertebrates that the moon is said to exert an influence. There are a number of references to this in the classical authors. Aristotle says that the ovaries of sea-urchins acquire a greater size than usual at the time of full moon. Cicero notes that "oysters and all shell-fish increase and decrease with the moon," and Pliny states that "careful observers attribute to lunar power the increase and decrease of the bodies of oysters and all shell-fish." The same belief is common to-day in many of the fish-markets around the Mediterranean and in other parts of the world. The amount of edible matter in sea-urchins, molluscs, and crabs is stated to vary with the phases of the moon: the animals are said to be "full" when the moon is full, and empty at new moon. Some gourmets maintain too that the taste varies with the moon.

With the object of testing the truth of the popular statement I made systematic examinations of the testes and ovaries of a sea-urchin (*Diadema setosum*) at Suez during the summers of 1920 and 1921. For this species of Echinoid the reports of the fishermen turned out to be founded on fact to a surprising degree. There is a periodic reproductive cycle correlated with the lunar period, the genital products being spawned into the sea round about each full moon during the breeding season. After spawning the testes and ovaries become reduced in bulk, the declining phases of the moon being occupied by recuperation and the commencement of the preparation of fresh genital products. After the new moon these increase in ripeness and in bulk, and with this development the visible size of the genital glands grows once more.

Microscopic examination of the gonads of a number of individuals between the first quarter and full moon shows the majority to be swollen and packed with fully formed spermatozoa or eggs. A small proportion are "spent," that is they show evidence of having lately extruded their genital products. A week later the relative proportions are reversed; some individuals have gonads still full of spermatozoa or eggs, but most are "spent." Between the third quarter and the new moon all gonads are shrunken in size and contain nothing but developing spermatocytes or oöcytes. From now onwards until the first quarter of the next moon these cells show progressive stages in development into spermatozoa and eggs, destined to be spawned round about the time of full moon. This lunar cycle is repeated throughout the breeding season.

In seeking a causal connection between the reproductive rhythm and the lunar month an influence of the tides first suggests itself. But whereas *Diadema* has a single reproductive cycle in each lunation there are two spring and two neap tidal periods, i.e. a double cycle. However, during the summer months at Suez the new moon spring tides have a greater range than the full moon springs, so that the maximum tidal range is attained once only during each lunar month. The higher and lower water at the new moon springs might conceivably react on the Echinoids by the different hydrostatic pressure (affecting, *e.g.*, the tension of dissolved gases) or by causing the animals to be at a greater or lesser distance than usual from the source of oxygen or of light. But the average excess tidal range at new moon springs over that at full moon springs during the period studied was only 58 cm. This small difference could scarcely affect the urchins, for they are not sessile animals, but move actively and their vertical range of migration during the course of an hour is often far in excess of this figure.

The possibility of tidal influence could be tested by keeping urchins in a floating cage. If the lunar reproductive cycle were thereby abolished the tidal connection would be demonstrated ; but a contrary result from the experiment would not dispose of a possible influence of the tides, for an established rhythm in a physiological process is often persistent after the original cause has been removed. One has only to recall the case of *Convoluta*, a marine turbellarian worm which lays its eggs only at neap tides. It has been found that animals hatched and reared in the laboratory keep the same egg-laying habit (Gamble and Keeble, *Quart. Journ. Micr. Soc.*, 1906). In any case the experiment of eliminating the tides was unfortunately impracticable with *Diadema* owing to its size. Fully grown specimens measure over one foot from tip to tip of the spines, and it was impossible to obtain large enough floating boxes to contain a hundred or more individuals. But I intend to seek further evidence regarding the possible effect of tides by studying Echinoids in localities with greater and lesser tidal ranges than at Suez. I am convinced, however, that if a similar lunar reproductive cycle exists in the sea-urchins at Naples or Plymouth it is very little pronounced. For I have made use of the Echinoids at these places to obtain spermatozoa and ova for other experimental purposes for months continuously without ever noticing a rhythmic variation in condition or quantity of genital products. At Suez the period in each lunar month when spermatozoa and eggs are unobtainable would necessarily force itself upon the notice of the investigator.

The possibility of a direct effect of the light of the moon on the Echinoids could be tested by keeping specimens in the dark. Although the large size of *Diadema* again precluded this experiment at Suez, I intend to carry it out in another place with a smaller Echinoid. If the light has an effect it must necessarily be more constant in the cloudless summer nights of Egypt than in Europe.

Another possibility was that the light of the moon might act by causing the urchins to feed either more or less on moonlit nights. A systematic examination and comparison of the gut-contents of specimens taken at dawn (1) after a moonlit night, and (2) after a night without moon, showed, however, no difference either in quantity or nature of food.

The sea-urchins fished at Alexandria are locally believed to change with the moon in the same manner as the Suez ones. A parallel investigation of the Alexandrian urchins (*Strongylocentrotus lividus*) has shown, however, that in this case there is no lunar reproductive cycle. The Alexandrian species is identical with one of those fished and eaten at Naples, which, as mentioned above, has apparently no lunar cycle. How, then, are we to account for the ancient Greek and Roman belief in such a periodicity, and for the present-day statements in the Naples and Alexandria fish markets? I can only suppose that what is a fact at Suez has come uncritically to be believed all over Egypt, and that in very early times the Egyptian belief was brought to Greece, whence it spread, and has remained all around the Mediterranean coasts.

In addition to sea-urchins, it is believed in the Egyptian fish-markets that the flesh of mussels and crabs varies in quantity with the moon. In mussels, just as in sea-urchins, the genital glands form the bulk of the edible material, in crabs it is the muscular tissue. It is these tissues, then, that are supposed to vary in bulk with the changing moon, but I have found that this is not true. Presumably what really occurs in the sea-urchins is imagined by the people to take place in all "shell-fish."

The eggs of the sea-urchin when spawned into the sea are normally fertilised immediately by spermatozoa shed by a neighbouring male. In the course of a few hours the segmenting eggs develop into free-swimming ciliated larvæ which rise to the surface of the sea, where they become members of the great floating population known as the plankton. Now it is obvious that the periodic spawning of *Diadema* must be reflected in the plankton of the Gulf of Suez. The larvæ of this sea-urchin swimming at the surface of the sea must vary in numbers and in stage of development with the phases of the moon. In the same way there must be a lunar periodicity in the frequency of the pelagic larvæ of all other animals which have a lunar reproductive cycle. By studying plankton from different parts of the world I hope to discover which these animals are.

Up to the present the best known case of lunar reproductive periodicity scientifically investigated has been that of the Palolo Worm (Friedländer, *Biol. Centralbl.*, 1898–1901). This Polychæte (*Eunice viridis*) lives in the coral reefs in Samoa and other Pacific Islands. At the last quarter of the moon in October and November the posterior parts of the worms laden with genital products become detached from the anterior portions. While the latter remain among the coral the genital segments swim up to the surface of the sea, where they shed their spermatozoa and eggs. This swarming takes place at low tide on several successive days, the swarms being composed of enormous numbers of individuals which die after having spawned. The swarming worms are fished by the natives who relish them as a delicacy, and each year the fishermen judge the right time to prepare nets and boats for the catch by the state of the moon. It is not known what gives the stimulus to the worms to spawn, whether moonlight, tide, or some other physical change depending on the moon.

In Japan there is another Palolo (*Ceratocephale Osawai*) which swarms both at full and new moons (Izuka, *Journ. Coll. Sci. Tokyo*, **36**, 1903). Here the bilunar periodicity is presumably due to the spring tides, but we are ignorant of the manner in which the greater tidal range may react on the animals. In the Atlantic yet another kind of Palolo (*Staurocephalus gregaricus*) swarms usually at the last quarter, but occasionally also at the first quarter of the moon (Mayer, *Carnegie Inst. Pub.*, **102**, 1909). Mayer was the first to abandon the observational method which had proved so unfruitful in seeking for a causal explanation of lunar periodicity in reproduction. He carried out direct experiments. Eleven mature worms were placed in a floating (*i.e.* tideless) box thirty days before the swarming time was due. Only four of these worms swarmed, whereas in nature all mature individuals swarm. Thus the tide appears not to be the sole cause of swarming, unless, of course, those worms which swarmed in the floating box did so owing to a tidal rhythm previously acquired, as in the case of *Convoluta* mentioned above. Mayer also put twenty-two worms in floating boxes protected from the moonlight. None of these animals swarmed. The light seems therefore to be a necessary contributory cause for swarming. These valuable experiments should be repeated with a greater number of individuals. It is obvious, however, that whether light, tide, or some other factor gives the worms the stimulus to leave their holes in the rocks and swim up to the surface, some influence which varies with the lunar period must affect the worms at a date long anterior to the swarming time. For in order that all the worms should be sexually mature and ready to swarm together at, say, the last quarter of a certain moon, the development of the genital organs must have been initiated in all of them together at some definite previous lunar phase.

There are certain other marine worms which show a lunar reproductive periodicity. Potts found that sexually mature individuals of *Odontosyllis* in British Columbia swarm once a year from the sea-bottom to the surface in order to spawn. This occurs in August, during the first or third quarter of the moon (*Proc. Camb. Phil. Soc.*, **17**, 1913). At Bermuda this worm also exhibits a lunar periodicity in swarming. Another Polychæte, *Nereis*, at Woods Hole, Massachusetts, swarms at sunset throughout the summer months, but during the waning phases of each moon only (Lillie and Just, *Biol. Bull.*, **24**, 1913; and Just, *Biol. Bull.*, **27**, 1914). At Naples *Nereis* swarms round about both the first and third quarters of the moon from October to May (Hempelmann, *Zoologica*, **25**, 1911). The latter bilunar, *i.e.* apparently tidal, periodicity is remarkable since the tidal range at Naples is much less than at Woods Hole, yet swarming at the last-mentioned place is not correlated with the tides. The behaviour of *Nereis* is the more anomalous since twenty years' observation in the Thames estuary by Sorby (*Journ. Linn. Soc.*, **29**, 1906) failed to detect any lunar rhythm in the swarming of this worm. *Amphitrite*, also a Polychæte, lays its eggs at new and full moon spring tides at Woods Hole (Scott, *Biol. Bull.*, **17**, 1909). Scott supposes that the higher temperature of the sand flats on which the animals live, due to the abnormally low water at spring tides, together with a more abundant food supply at these times, are the immediate causes of the tidal reproductive cycle.

Among Molluscs the only case I know of was communicated to me in a letter by Dr. W. J. Crozier, who states that at Woods Hole a chiton spawns at the time of full moon.

To my knowledge the only other case of reproductive rhythm in animals correlated with the lunar period is in the human race. Arrhenius (*Skand. Arch. f. Physiol.*, **8**, 1898) showed by a statistical investigation of 25,000 cases that there exists a low correlation between the frequency of births and the tropical lunar period of 27·32 days.[1] Rather more births take place in a certain part of the tropical lunar month than in the remainder. Since this nativity rhythm might depend upon a periodicity in menstruation, Arrhenius then set to work to find out whether the latter exists. His material was furnished by 12,000 cases from Stockholm maternity hospitals, where the date of the last menstruation before the onset of pregnancy is recorded for each patient admitted. The same kind of periodicity was found as in the case of the births, but to a more pronounced degree. Taking the day on which the moon passes through the ecliptic from North to South as the first day of the tropical lunar month, the curve giving the frequencies of menstruation for each day in the month gradually descends to a minimum on the eighteenth day, when there are 6·5 per cent. fewer cases than the average for all the days of the month, and then gradually rises again to reach a maximum at another part of the month. In each individual the onset of menstruation depends, of course, upon a number of physiological and psychical causes, which occur without any rhythm. In addition there is a rhythmic causative factor having the period of the revolution of the moon. This

[1] This is the time taken by the moon to make one circuit of the heavens. The synodical month or lunation of 29·53 days is the time in which the moon goes through her phases.

factor is weak and will only make itself felt when acting in conjunction with the other causes. Menstruation may occur, then, on any day according to the resultant effect of all the causative forces acting upon the person, but in more instances than not it will fall in that part of the tropical lunar period in which the periodic factor is acting.

Arrhenius suggests that the factor in question is the amount of electricity in the atmosphere which he has shown to vary rhythmically with a period of 27·32 days. But in addition to this period the atmospheric electricity has a shorter (non-lunar) one of 25·93 days. If now the same shorter period could be demonstrated also in the menstruation figures, the possibility of a causal connection between the two phenomena would be heightened. Further investigation showed that the shorter period was present in the case of menstruation. In addition, the effect of the two periodicities should be to cause the average length of the menstrual period to be 26·605 days. The average for 1834 individuals in Denmark was found to be 26·68 days.

Arrhenius demonstrated the same double periodicity for epilepsy, but found it to be absent for bronchitis and mortality.

Among plants the sole authentic cases of a lunar rhythm in reproduction seem to be among the Algæ. *Dictyota dichotoma* is a common marine alga found in various parts of the world. At Beaufort, North Carolina, this plant produces one crop of sexual cells in each lunar month (Hoyt, *Bot. Gaz.*, **43**, 1907). The same species at Bangor, Plymouth (Williams, *Ann. Bot.*, **19**, 1905), and Naples (Lewis, *Bot. Gaz.*, **50**, 1910) has a tidal reproductive rhythm, *i.e.* two cycles per lunation. This difference in behaviour in different localities has not been explained. It is the more problematical since the tidal range at Beaufort is small, resembling the Mediterranean conditions and differing widely from the considerable tidal range on the English coasts. The figures for the average tidal ranges are as follows: Bangor 17·9 feet, Beaufort 2·8 feet, Naples 1·0 feet. *Sargassum*, too, shows a bilunar reproductive cycle (Tahara, *Bot. Mag. Tokyo*, **23**, 1909).

Popular beliefs in a favourable influence of the moon on plant growth are both world-wide and ancient, although most of them are probably on a par with the superstition that a waxing moon increases, a waning moon decreases, any process such, for instance, as the acquisition of wealth. Seneca, Galen, and other classical authors speak of the moon as hastening the maturation of fruits. Athenio is more precise, writing that "cucumbers in gardens grow at full moon, showing a visible development, and so do sea-urchins." This quotation is of special interest in relation to a common belief of the modern Egyptians that melons, marrows, and other fruits of the Natural

Order Cucurbitaceæ grow most rapidly on moonlit nights. An investigation of the rate of growth of these fruits, extended over three months, has shown me, however, that there is no basis at all for this belief. As the lunar influence is supposed to show itself especially in these cucurbitaceous fruits, it may safely be assumed to be absent in all fruits.

Nevertheless, since the popular belief in the existence of a lunar cycle in sea-urchins has turned out to be so unexpectedly true, one is bound to ask whether any other of the superstitions about plants too are based on fact. It is conceivable, for instance, that moonlight may have a photosynthetic effect. Kofoid (*Bull. Illinois State Lab. Nat. Hist.*, **8**, 1908) found a lunar periodicity in the frequencies of plankton organisms in the Illinois River. Allen (*Univ. Cal. Pubs. Zool.*, **22**, 1920) discovered the same thing in the San Joaquin River, California. The maximum frequency of Algæ occurred at full moon, that of Crustacea a little later. While the crustacean presumably follows the algal maximum because the animals feed on the plants, Kofoid attributes the algal maximum occurring about full moon to a photosynthetic effect of moonlight. He supports this hypothesis by reference to experiments of Knaute (*Biol. Centralbl.*, **18**, 1898), who states that he found the oxygen content of water containing *Euglena* to be higher in moonlight than in darkness, which means that the moonlight causes photosynthesis. Knaute says that the photosynthetic effect of moonlight is to that of sunlight as 2 : 9. This is a surprisingly high ratio, since the light of the sun is about 600,000 times that of the full moon. In view of the great theoretical importance of lunar photosynthesis, if it really exists, I am at present repeating Knaute's work. Preliminary experiments, using, not an Alga, but the aquatic flowering plant *Elodea*, have shown that here the lower limit of illumination necessary for photosynthesis is of a totally different order of intensity from even full moonlight. The method used was based on the change in hydrogen ion concentration in the water in which the plant was placed, due to the change in its carbon dioxide content.

There are, however, two demonstrated effects of moonlight upon plants. Firstly, Musset (*C. R. Acad. Sci.*, 1883 and 1890) showed that a number of flowering plants are positively phototropic to moonlight. The stems bend towards the moon and during the course of the night move round to follow his path. Secondly, Loftfield (*Carnegie Inst. Publ.*, 314, 1921) states that at night stomata open as a result of illumination by moonlight. The consequent periodic opportunity for increased transpiration and respiration might conceivably cause other rhythmic changes in the plant, with a lunar period.

In conclusion, two cases of lunar effects on the migration of fish must be mentioned. The first concerns herring, and is of peculiar interest since the rather intricate causal connection has been elucidated. The work was done by Pettersson (*Quart. Journ. Roy. Meteorol. Soc.*, **38**, 1912). Herring are not found in the Baltic because the water is not sufficiently salt. They migrate into the Kattegat however, with an undercurrent of salter water which exists beneath the less dense surface layers. This undercurrent is oscillatory and the movement shows itself by changes in the level of the deep salter water. The crests of the submarine waves occur at intervals of about thirteen and a half days, that is, the undulatory movement has the tropical lunar period of twenty-seven days and depends on the moon's declination. That the herring move with the salt water is shown by the fact that the dates of the greatest herring catches are those on which the crests of the waves of salter water occur. But this is not all. During the last century and a half the years of maximum and minimum herring fisheries are found to coincide with the years of maximum and minimum declination of the moon, which are 9·3 years apart. It may be presumed that the fishery has this period of 18·6 years because of a variation of the salter undercurrent with the same period. The herring fishery has also a longer period which can be traced back 1,000 years. The maxima are 111 years apart. This is the greater sunspot period, but since $6 \times 18{\cdot}6 = 111{\cdot}6$, the moon's declination may again be the real cause.

The second case of a lunar effect on the migration of fish is the following. Dr. Johann Schmidt informs me that Danish eel fishermen, who catch silver eels with nets in the shallow water as they migrate out of the Baltic in the autumn, expect to obtain better catches in the interlunar periods than when there is moonlight. In Egypt, too, the eel fishermen look forward to the best catches when there is no moon. Mr. G. W. Paget, Egyptian Government Director of Fisheries, suggests in explanation of this a direct effect of the light of the moon in stopping the migration of the eels, basing his opinion on successful experiments carried out in Denmark on artificially stopping eel migrations with acetylene lamps. The Italians, too, light fires when they want to interrupt a migration in order to clear their nets.

I should be grateful if any readers of Science Progress who know of popular beliefs in lunar influence on animals or plants would communicate them. On closer investigation some may prove to be as well founded on fact as the case of the sea-urchins.

# NOTES

**Scientific Politics.—IV. "Public Opinion and Propaganda."**

"DON'T ask any questions," said Mr. Pickwick to the faithful Snodgrass at the Eatanswill election. "It's always best on these occasions to do what the mob do."

"But suppose there are two mobs?" suggested Mr. Snodgrass.

"Shout with the largest!" replied Mr. Pickwick.

Mr. Pickwick's interest in philosophy, which included the immortal "Speculations on the Source of the Hampstead Ponds, with some Observations on the Theory of Tittlebats," unfortunately did not lead him to explore the profoundly interesting problem which the contest of Fizkin and Slumkey brought before his eyes—and ears. It must be reluctantly confessed that Mr. Pickwick had no political principles, and cared more for hot punch than high politics, or the ebb and flow of public opinion.

Perhaps we may take up the question, or rather questions, where he left it. What makes the mob shout? Why are there two mobs? What is public opinion? What makes it change? Why is it that a Government which can do no wrong one day, can do nothing right the next?

These conundrums are surely worth answering. But nobody in politics attempts to answer them; and, indeed, they belong to psychology and history rather than the hurly-burly of current politics—to the spectator rather than the participant in the fight.

The whole idea of representative government is that the voter is a reasonable person, who, by the exercise of his reason, decides which of two or more conflicting policies or persons should be entrusted with the power to rule. In theory he follows the actions of the Government and its opponents with close and unremitting interest, he studies questions of home and foreign affairs with careful attention, digests blue-books and remembers despatches, reads Parliamentary reports and platform speeches, and, finally, at the appointed time, makes his decision calmly and even solemnly as the trustee of a grave national responsibility.

In practice, as Mr. Pickwick discovered at Eatanswill, things do not work out quite like that. The mob shouts itself hoarse; another mob breaks heads. Intimidation is not unknown; corruption has been heard of. Appeals are made to personal or class interests or local prejudices; the larger view is somewhat to seek. If reason triumphs in the end—it always does, according to the victor—passion is vastly more in evidence on the polling day.

The people is always distrusted and sometimes execrated by its leaders, but the leaders are nothing without the people from whom they draw their power. In the last resort, the people, of whom the mob is a visible unit, is public opinion; and it is because it is decisive that it is appealed to, and because it vacillates that it is distrusted.

Through the whole of history we see that moving silent background of public opinion; it is the canvas on which the picture is painted, the sheet on which the cinema plays, the restless sea with hidden and dangerous currents on which the ship of State must float or sink. The malleable multitude, patient and passionate by turns, credulous one minute and sceptical the next, is the ultimate arbiter in human affairs.

Admittedly, public opinion operates only in certain directions, and on that account it is generally ignored by men of science, as—to be quite frank—it generally ignores them. Public opinion has nothing to say to ascertained facts; it does not, for example, take sides over the differential calculus. And a large class of subjects interest it only spasmodically, or not at all. There is no real public opinion on æsthetics, which does not interest the crowd. It has a real sense of beauty, but when it does happen to concern itself with art, its attitude is generally destructive; it destroys what it does not understand, as in the Puritan Revolution in England, and the Bolshevik Revolution in Russia.

It is less hostile, particularly in this country, to science, but its usual indifference is easily turned to hatred—the hatred of the ignorant for a mysterious power which it sometimes respects and sometimes fears. A mob burned the library at Alexandria which contained the knowledge of the ancient world; the leader of the mob in the French Revolution declared that "the Republic has no need of science." Bolshevism in Russia followed the lead of Paris.

The Church, too, often persecuted men of science in its day of authority; its action seems never to have been unpopular. Indeed, the Inquisition was probably rather a democratic institution; it burnt the minority with the approval of the majority, and it provided, from time to time, a series of entertaining, and to the orthodox even edifying, public spectacles. If the Church had retained its strength in the nineteenth century, it would certainly have burnt the *Origin of Species*, and its action would have been approved by the crowd, and endorsed by both Gladstone and Disraeli, and the bulk of the daily Press.

On these matters, counsel for the defence can only enter a plea of guilty, with the excuse—if it is an excuse—that public opinion was insane at the time to discuss a matter which it was not competent to judge. Logically, it is little better fitted to decide on politics or religion, but at first sight it seems supreme in those departments.

Yet both politics and religion distrust public opinion, and try to minimise, to control, or, in extreme cases, to exclude it altogether. They begin by appealing to the public; they end by denying the competence of the public to decide. This curious and suggestive contrast deserves further examination. The supremacy, or at least the apparent supremacy, of public opinion in politics and religion is the foundation of pragmatism. "The faith is true which works"; and the doctrine is so far justified that the prophet or politician who can get no followers does not count. Mohammedanism nearly perished at its birth, Buddhism only survived because it crossed the Himalayas, and Christianity because it spread to Europe. Hundreds of religions which missed the touch of the universal, have remained local or tribal cults that must go down in time before the more comprehensive creeds.

In each case the process was the same, but further examination shows that the new faith, so far from following public opinion, really goes against it, openly despises and denounces it, and in the end succeeds in changing it. Every new creed depends on its followers at the start, but these are a bare minority conscious of the opposition of the mass, yet still more conscious of the truth of their belief. They are in no sense public opinion; but this minority defies, transcends, and in the end conquers and converts public opinion. It is, therefore, not public opinion which makes the religion, but the religion which makes public opinion.

Politics are essentially similar. The savage chief has no power until men come to his standard; a leader is not a leader until men will follow him, and only the belief that he is worth following will induce them to follow in the first instance. Once the effective minority is on his side the crowd will be persuaded or compelled to follow, but the ruler with political instincts quickly realises the weakness of his prop. Religion has secured itself on the quicksand of public opinion by the anchor of divine revelation, but politics from its very nature knows no such stay. For that reason the State which wishes to secure permanence relies in every age ultimately not on public opinion, which is "blown about by every wind of doctrine," but on disciplined force, which stands between the caprice of the mob and the stability of the realm; for that reason, too, the first action of the revolutionists in Russia was to abolish discipline in the army, and the first hope of the revolutionists in this country was to corrupt the police.

A classic anecdote has preserved an illustration of public opinion in the early days of the Roman Empire. When St. Paul was shipwrecked on Melita a viper fastened on his hand and the barbarians said, "No doubt this man is a murderer, whom, though he hath escaped from the sea, yet Justice hath not suffered to live." But when they "beheld nothing amiss come to him, they changed their minds and said that he was a god."

That anecdote explains clearly enough the necessity of government by force among savages. Self-preservation is the first law of every government, as of every individual. But when public opinion is so volatile that the same man ranks as a murderer and a god in the same half-hour, government by public opinion is impossible. There must be a certain stability in public opinion before government can place any reliance on it.

It is not very difficult for the historian to gauge the part played by public opinion in any age. In the Roman Republic, for instance, opinion was obviously influential in politics; its working is manifest at every turn. Under the Empire it seemed to decay, but in fact it did not cease to operate. What happened was that the Empire secured absolute political stability, and apart from administrative details (which were a matter for experts) and military revolutions (in which opinion was helpless) there was nothing to discuss. But the public opinion of the time remained vigorous and active; and deprived of a political channel, it found vent in theological discussion. Where Cato and Cicero had discussed forms of government, Arius and Athanasius discussed faith and doctrine; and the tumults which these disputes evoked shows that public opinion followed the definitions and counter-definitions of rival creeds with keen interest. Popular riots accompanied the General Councils of the Church; it is as though a Cockney mob broke into the proceedings of the Aristotelian Society while Professors Wildon Carr and Whitehead are discussing the nature of the Absolute.

As the Church became supreme, however, even this avenue for public opinion was blocked. When the Christians were in a minority they were persecuted; when they became a majority they persecuted each other; but in the Middle Ages there were no persecutions, only crusades—there was nobody left to persecute until the Reformation, by reviving religious differences, again brought public opinion to the fore.

Its operation was everywhere the same. In every country it attacked the minority with gusto. This *reductio ad absurdum* of Pragmatism therefore demonstrates that if the faith is true which works, truth varies according to geography. Catholicism was true in Spain, Lutheranism in Germany, Calvinism in Holland, because the majority said so.

It is because public opinion is so variable that a cynic once declared that the majority is always wrong ; that Lord Rosebery in one of his essays remarked that " politics are the sport of circumstance, and principle the slave of opportunity " ; and that men of science, accustomed to the certainties of the laboratory, are apt to ignore a force which seems both potent and ineffective, certain only in its uncertainty, and at once irrational and inconclusive.

But this attitude is really as unscientific as Mr. Pickwick's. The business of science is to find the rational element in the apparently irrational. Public opinion is as uncertain as the wind ; but the meteorologist knows the causes which bring about a change of wind, although he cannot accurately foretell them. Similarly, the student of history can analyse the more complex causes which bring about a change of public opinion ; and although he too is unable to predict them in advance, he has sufficient materials to construct the basis of a theory of communal psychology.

Such a study will be found to differ very considerably from the psychology of the individual. It is, in the first place, less concerned with reason and more with will. Ten men in a crowd are not ten times as rational as one man ; the probability is that they will be less rational. But ten men in a crowd will have ten times the volition of one, and they may have more, for the normal will of the individual is increased by excitement, propinquity, and the suggestion of action. Reason is the individual balance, and it is, therefore, less operative when individuality is lost in the crowd ; at such times the rational check on the emotions is minimised or suspended, and the will, reinforced by those emotions, is supreme.

When the crowd is disciplined, its will is united ; an army is nothing more than a trained and disciplined crowd, whose will is directed to one end. Its will is irresistible unless it encounters a stronger communal will ; but the ordinary crowd is a merely fortuitous concourse, and its will is not thus unified. It may be irresolute, until its emotions are roused by the leader ; and it is possible that its will becomes sharply divided, in which case there are the two mobs of Mr. Pickwick's experience, or even riot or civil war. Thought is primarily the consequence of action, not action of thought, even in the individual; but in the crowd this characteristic is intensified. The mob acts first, and thinks afterwards.

It has been demonstrated that the processes of thought in the individual occupy a definite time from ingemination to completion; and we are all familiar with the fact that when a thought is presented to us from outside, the more remote it is from our accustomed mental processes, the longer it takes to assimilate. In the crowd this time-reaction is almost grotesquely exaggerated. An obvious proposition—"Down with the House of Lords," "We want eight and we won't wait," "Hang the Kaiser"—requires no mental effort and is understood at once; it produces instant reactions, of approval or disapproval. But a more novel or more recondite suggestion may require years, and even generations, before it is generally understood. It has to sink in, and some heads are very thick. But the slow working of the more recondite suggestion may have a permanent effect on public policy, whereas the catchword which raises public enthusiasm to fever heat is forgotten in a few months, and almost unintelligible after some years. Nothing on earth is quite so dead as an old political speech.

Probably the greatest difficulty of the propagandist is to secure attention; proverbially he finds it better business to be attacked than ignored. But it is a world of multitudinous variety, people are interested in many things, and the attention of the crowd is easily distracted. (A stray dog in church will notoriously ruin the most eloquent sermon.) It is precisely because public attention is so easily distracted that the orator, like the advertiser, repeats himself—he is in fact advertising his own remedy for current ills—and thus repetition, which is suspect in literature, is essential in speaking. The reason is simple. The writer appeals to the individual whose attention is less easily distracted; the orator appeals to the crowd. Only the great orator can hold the attention of the whole crowd all the time; it is the highest triumph of technical efficiency in his art. And it is far more difficult to hold attention with a reasoned argument than with an emotional appeal; for that reason platform speaking to the general public is always more emotional than a speech in the House of Commons, which is a selected crowd. But even in the House of Commons, the emotional appeal will sometimes outclass the reasoned argument, because the House, although a selected crowd, is still a crowd; for the same reason appeals to a jury are more emotional than arguments addressed to a judge.

This fact constitutes one of the great difficulties of the modern democratic State, which is, at least nominally, ruled by public opinion. The demagogue knows perfectly well that an appeal to emotion pays him better than an appeal to reason, and he uses his knowledge to win an election. Two evils follow —the statesman who appeals to reason gets less attention, or is frozen out of politics; and the Government, which must obey reason, and not emotion in its policy and executive acts, finds itself hampered by pledges which either cannot be carried out at all, or can only be carried out to the detriment of the community.

The only cure for these evils is education—not necessarily the education of the school, or even the university, but of the world—and a sense of responsibility. The long tradition of parliamentary government in this country has in fact educated the older and more limited electorate, so that there is a certain stability in that section of public opinion; but the newly enfranchised seem conscious of their incompetence to form a judgment, and quite frankly attend political meetings to obtain information; and not as partisans convinced in advance and ready to cheer the echoes of their own views.

It is sometimes suggested that whirlwind campaigns, platform speeches, and a popular Press are modern evils which democracy has brought in its train. But these things are only organised propaganda, which is simply an attempt to influence opinion; and propaganda is the oldest and most widespread of the arts.

According to the Bible it accounted for the fall, and according to anthropology, it was partially responsible for the rise of man. Eve practised it on Adam when she persuaded him to eat the apple against his will; Lord Northcliffe adopted very similar methods, with less successful or less disastrous results, when he advocated standard bread. It is true that those who reject the Garden of Eden story as itself an example of successful propaganda point to the charcoal pictures and ceremonial relics of far earlier times as witnesses against the truth of Genesis. But the pictures and the ceremonies are sufficient evidence of primitive belief, and the method of its propagation. Palæolithic man has vanished, but his propaganda remains.

From the cave-man to the caucus is a long step, but the art of propaganda is essentially the same in all ages. It must influence and consolidate opinion; it must be a little, but not too far, in advance of the crowd. For that reason, the great discoverers are not good propagandists; they look too far ahead. Their objective is out of sight of the multitude, which may reverence them, but can hardly follow them. They must have an interpreter, who popularises their opinions by diluting them. Truth, according to the more cynical propagandists, is like whisky—only the strong can take it neat; the average man prefers it mixed. The gas in the soda makes it more palatable. Admittedly, there is always plenty of gas in the political soda.

Propaganda in practice usually means the presentation of a half-truth as though it were the whole. There is always something to be said on the other side, but the propagandist does not say it. He must convey certainty, or he is lost. It is probably for that reason that men of science are, on the whole, the worst propagandists in the world. Science alway admits the objections to its hypotheses ; politics never. But so long as science includes psychology in its fellowship, it may disdain, but it cannot be entirely disinterested in either the methods or the results of propaganda. The propagandist is an experimenter like the chemist, but in a far more delicate and dangerous medium—human personality in the mass. His methods are sometimes as crude as those of the old alchemists, and occasionally there is an unexpected explosion. But undeniably he produces results.

It is what he is there for ; the propagandist is a fisherman. Nobody asks him for a theory of tidal action, or a new hypothesis of the formation of rivers ; it is his business to catch fish, and only his unsuccessful rivals ask whether he tickled the trout or landed it fairly.

The human voice is, and will probably always remain, the chief instrument of propaganda. The reason is clear. A speech is personal, print impersonal ; speech appeals to the emotions of the crowd, print to the reason of the individual. The great orator plays on the feelings of his audience like a trained musician on the piano ; every tone, every gesture, every cheer, and even every interruption, adds to the effect. Read the same speech the next morning, and cold type has utterly transformed it. The moving denunciation that brought men to their feet is now sheer rhetoric, the solemn appeal that drew tears is shoddy sentiment ; the righteous indignation is laboriously calculated, and the majestic peroration a mere string of adjectives : the fire has gone, and only the ashes remain.

Print has other disadvantages. Few people read books, at least serious books ; and the political novel never converted anybody. The only novel with a purpose that has been effective as progaganda is *Uncle Tom's Cabin.*

In the long-run, indeed, the printed word will accomplish more than the spoken. The best oratory has something of the local and ephemeral ; its appeal is here and now ; but the pen has something of the eternal, and it slowly permeates the world with a new idea which does not die. The speaker who is too far ahead of his time lacks an audience ; the author in the same case finds his audience when he is dead. Propaganda in book form is slow, and in these days men want quick results.

Journalism has attempted to overcome these handicaps by gaining the same immediate attention for the printed as the spoken word. Its success has been emphatic, particularly during the past few years; everybody reads newspapers now, and many people read three or four a day.

Nobody would dispute the power of the Press; indeed, politics, like the pulpit, has often shown itself more than a little jealous, and while it asks favours in private, is apt to denounce, or at least disavow, the newspapers in public—a pleasantly human contradiction at Westminster that sometimes amuses Fleet Street.

But most thoughtful journalists will admit themselves dubious whether the Press has much real power, and still more doubtful whether it is increasing. As a purveyor of news, it is, of course, unique. But the sale of news by itself gives no more power than the sale of any other article in universal demand; it is the views that count as propaganda, and the influence of newspaper views on public opinion may easily be exaggerated.

In 1905, for instance, the Press, and particularly the London Press, was predominantly Unionist; but the General Election yielded a huge Liberal majority. In 1918 there were several Liberal dailies and no Labour dailies, while the Labour weeklies were obscure and inadequate sheets; but the Liberal party shrank to a bare handful, while Labour more than doubled its representation. Since 1918 Labour has established a daily newspaper—the communist *Daily Herald*—but the communist faith has perceptibly declined, and political Labour has not apparently increased its authority.

It is the same with personal as with public matters. Mr. Asquith ignored the Press; it did not prevent him from becoming Prime Minister for eight years. Neither Mr. Lloyd George nor Mr. Winston Churchill has been wholly indifferent to Fleet Street, possibly because both have been denounced year in and year out by powerful newspapers; yet neither has found his position impossible, as it should have been long ago, could leading articles and headlines have decided the fate of statesmen.

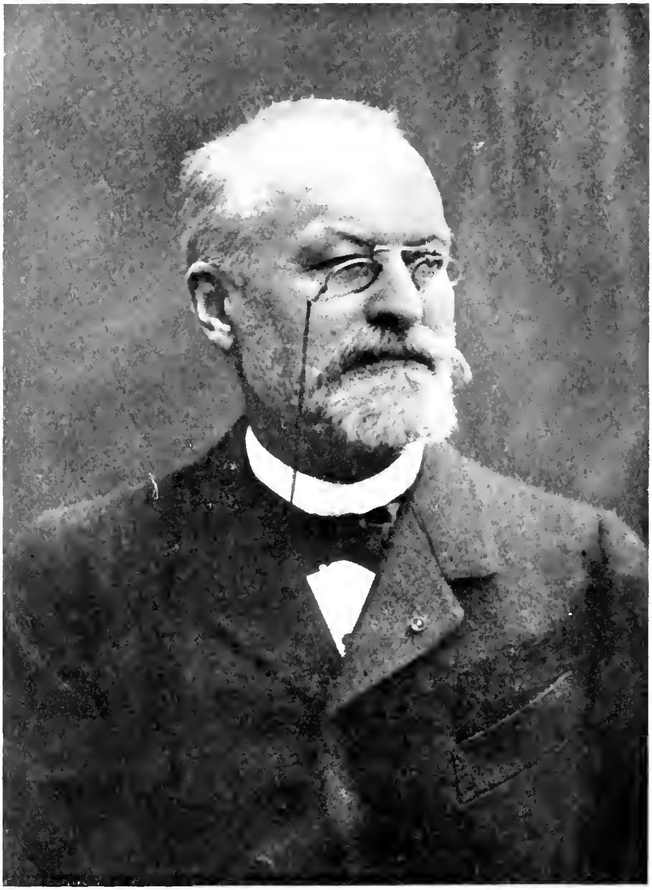
On the other hand, the Prime Minister has seen, and has at least not discouraged, the new Coalition Press that has sprung up since 1916. By a series of singular coincidences, titles have suitably rewarded the faithful proprietors of these journals. But their large circulations and valiant propaganda have not noticeably increased the popularity of the Government, which has fluctuated visibly month by month according to the events, and not according to the comments of the day.

The late Prof. Schreiner is said to have remarked that "five-sixths of the people in this country allow their newspapers to do their thinking for them." It would be more true to say that five-sixths of the people do their own (political) thinking, and either choose a newspaper because it expresses their views, or take a newspaper because of its news service and ignore its political attitude.

Moreover, there is reason to believe that the propagandist power of the Press is diminishing. Leading articles are certainly less effective than they were—with the single exception of the *Morning Post* and *Manchester Guardian*, both newspapers of limited circulation—and the fact is instructive. A newspaper is, after all, a business proposition; it cannot afford to offend its readers, or its revenue from both circulation and advertisements will drop. But the more readers it has, the more likely it is to offend them if it takes a strong line on any subject; the result is that a journal with a very large circulation is tempted to avoid controversy if possible, and if controversy is inevitable, to avoid taking the unpopular side; like Mr. Pickwick, it prefers to shout with the largest mob.

To disguise its lack of political principle, the popular newspaper devotes more space to non-political matters; and in order to attract a large number of less critical readers, it indulges in sensation and "stunts." The *Daily Express*, for instance, recently suggested that Sir E. Rutherford's experiments on the atom might blow up the earth. Probably few of its half-million, or more, readers had ever heard of Sir E. Rutherford, and perhaps fewer still knew anything of the rudiments of chemistry; but the end of the world has been foretold and postponed so often by divines that a healthy scepticism apparently saved the populace from wrecking the laboratory at Cambridge. It was "a good story," but it did not bite. The simple truth is that public opinion takes a heavy discount off Press polemics and predictions. It reads these things, as it reads the popular novel of the day; but they carry no conviction.

But the ultimate reason why the newspaper fails as a propagandist is that the newspaper has to sell its goods, whereas propaganda escapes the laws of economics altogether. Martyrdom is always the most effective form of propaganda, because the man who will die for his belief is presumably convinced of its truth; whereas the newspaper has still to come out to-morrow. In the long-run, therefore, propaganda depends on the individual who will stake everything on the cause for which he stands; the Press may help or hinder, but it cannot decide, for it must follow rather than lead the general public.



CHARLES LOUIS ALPHONSE LAVERAN

**Charles Louis Alphonse Laveran, 1845-1922 (Dr. G. Franchini, Institut Pasteur de Paris).**

Le 18 mai dernier un grand savant est mort. Avec lui disparait un des fondateurs de la médecine moderne qui avec la découverte de l'hématozoaire du paludisme ouvrit à la science un vaste horizon jusqu'alors inexploré, c'est à dire celui des hématozoaires pathogènes. La mort du Prof. Laveran est un deuil pour l'humanité entière, car ses travaux ont puissemment contribué à améliorer les conditions d'existence des peuples. Grace à lui, d'immenses territoires sont desormais ouverts à la colonisation et des millions d'hommes peuvent vivre dans les pays chauds et y exploiter les richesses du sol. Des pays et des villes qui avaient été abandonnées parceque inhabitables à cause de ce fléau qui s'appelle " la malaria," aujourd'hui, grâce aux mesures prophylactiques, sont redevenus riches et populeux.

Né a Paris le 18 juin 1845, fils d'un médecin militaire, A. Laveran entra lui-même dans la médecine militaire. Il fit ses études à Strasbourg et il y passa en 1867 sa Thèse intitulée : *Recherches expérimentales sur la régéneration des nerfs.* En 1874 il était nommé professeur agregé à l'hôpital militaire Val-de-Grâce, où il resta jusqu'en 1878. Il fut alors envoyé en Algérie où il séjourna à Bône, puis à Constantine. C'est là qu'il devait faire la découverte qui immortalisa son nom. On ne peut mieux donner une idée du mérite du Prof. Laveran, qu'en reproduisant les termes par lesquels il a lui-même résumé la genèse de cette découverte. " *En* 1880, *à l'hôpital militaire de Constantine je découvris sur les bords des corps sphériques pigmentés, dans le sang d'un malade atteint de fièvre palustre, des éléments filiformes, ressemblant à des flagelles qui s'agitaient avec une grande vivacité en déplacant les hématies voisines ; dès lors je n'eut plus de doute sur la nature parasitaire des éléments que j'avais trouvés ; je décrivis les principaux aspects sous les quels se présente l'hématozoaire du paludisme, dans des notes adressées à l'Académie de Médecine et à l'Académie des Sciences* (1880–1882), *et dans un opuscule intitulé : Nature parasitaire des accidents de l'impaludisme, description d'un nouveau parasite trouvé dans le sang des malades atteints de fièvre palustre Paris* 1881. *Ces premiers résultats de mes recherches furent accueillis avec beaucoup de scepticisme. En* 1879 *Klebs et Tommasi Crudeli avaient décrit sous le nom de " Bacillus malariae " un bacille trouvé dans le sol et dans l'eau des localités palustres.*

*L'hématozoaire que je donnais comme l'agent du paludisme ne ressemblait pas aux bacteries ; il se presentait sous des formes singulières ; il sortait en un mot du cadre des microbes pathogènes* *connus, et beaucoup d'observateurs, ne sachant où le classer trouvèrent plus simple de mettre en doute son existence. . . .*"

On voit donc de ce que nous avons mentionné ci-dessus que pendant plusieures années le Prof. Laveran fut sur la brèche pour defendre son découverte. Mais lui même il en était sur "*il était impossible, dit-il, de ne pas reconnaitre un être vivant dans cette masse protoplasmique repoussant de ses fouets les globules rouges environnants.*"

En Russie à la même époque Danilewsky decouvrait les hématozoaires pigmentés des oiseaux, et Griffith Evans, aux Indes, découvrait le premier trypanosome pathogène. Le Prof. Laveran ne se laissa pas ébranler par le scepticisme qu'accueillit d'abord ses publications et une autre question le préoccupait ; c'est à dire le mode de transmission du protozoaire. Après la découverte du savant anglais Patrick Manson de l'évolution de microfilaires chez les moustiques, dans un travail en 1884 il posait nettement la question du rôle des moustiques dans la transmission du protozoaire du paludisme. Il ne cessa d'y revenir, et après la grande découverte du Prof. Ross en 1898 il eut le satisfaction de voir son hypothèse se confirmer. Et à propos de cette découverte, voilà ce qu'il écrivait lui même "*Ayant quitté les pays palustres, il ne me fut pas possible de vérifier l'hypothèse que j'avais fait. C'est au Dr. Ronald Ross que revient le mérite d'avoir demontré que l'hématozoaire du paludisme, et un hématozoaire des oiseaux très voisin de Haemamoeba malariae accomplissaient chez des culicides plusieures phases de leurs évolution et étaient propagés par ces insectes.*"

En 1894 le Prof. Laveran quitta la médecine militaire pour venir travailler à l'Institut Pasteur (1897). C'est là qu'il consacra uniquement son activité aux recherches de laboratoire et il fit une étude systématique des hématozaires pathogènes. Il fut un des premiers à étudier les *picroplasmes*, et en 1900 il commenca l'étude des *trypanosomes*, qu'il continua en collaboration avec le Prof. Mesnil, le Dr. Roudsky et autres jusqu'en 1914.

Il étudia d'une façon complète les *leishmanioses cutanées* et *internes*, les *tocsoplasma*, les *sarcosporidies*, les *amibes*, les *flagellés des insectes*, des *plantes*, etc. Ces dernières années Laveran s'était attaqué en collaboration avec M. Franchini au problema de la genèse des infections des mammifères à partir des flagellés des insectes. Et en collaboration avec le même il a publié des nombreuses brochures sur les *flagellés du tube digestif de nombreux insectes ematophages et phitophages, sur la spirochetose d'insectes et des plantes à latex, sur la flagellose des euphorbes, etc.*

Ce rapide résumé ne donne qu'une idée très pâle de l'activité scientifique du Prof. Laveran. Il n'était pas seulement un grand investigateur des maladies tropicales, mais encore un clinicien, ayant publié des interessantes recherches sur la fièvre typhoide et 62 observations de cas d'autres maladies. Il a publié encore des travaux sur le système nerveux et en particulier sur la régénération des nerfs. Les publications les plus remarquables sont : *Traité des fièvres palustres*, 1884—*Du paludisme et de son hématozoaire*, 1891—*Traité du paludisme*, 1898–1907—*Prophylaxie du paludisme*, 1903—*Trypanosomes et trypanosomiases*, 1904–1912—*Traité des leishmanioses*, 1917.

Toute sa vie fut dédiée au laboratoire, où il passa presque tout son temps. Pendant la guerre il se rendit aux armées pour des conseils d'Hygiène, et, dès le debut de la campagne de Macédoine, il redigéa des prescriptions prophylactiques visant le paludisme.

Les honneurs vinrent peu à peu au Prof. Laveran. En 1893 fut élu membre de l'Académie de Médecine de Paris et élu président de cette Académie en 1920. En 1901 entra à l'Institut de France. En 1907 le prix Nobel de Médecine lui fut décerné. En 1908 il fonda la Société de Pathologie Exotique de Paris. Il était membre ou correspondent des principales Académies et Sociétés de l'Europe et du monde entier. Il était commandeur de la Légion d'Honneur et avait le titre recherché de membre étranger de la *Royal Society*. Le nom du Prof. A. Laveran sera imperissable et lui survivra comme celui d'un grand bienfaiteur de l'humanité.

**Notes and News.**

On the occasion of the King's birthday knighthoods were conferred on the following well-known scientists : Prof. W. M. Bayliss, of University College, London ; Prof. F. W. Keeble, of Oxford, and Dr. E. J. Russell, Director of the Rothamsted Experimental Station.

Sir William Pope has been elected President of the International Union of Pure and Applied Chemistry for the period 1922–5. The next meeting of the Union is at Cambridge in June 1923.

The Albert medal of the Royal Society of Arts for 1922 has been awarded to Sir Dugald Clerk.

Sir Humphry Rolleston has been elected President of the Röntgen Society for the session 1922–3.

Sir Thomas Holland succeeds Sir Alfred Keogh as Rector of the Imperial College of Science. The new Rector is an old student of the Royal College of Science, and in 1919 was President of the Old Students' Association of the College. Among the many important positions he has filled was that of Director of the Indian Geological Survey.

Col. E. M. Jack succeeds Sir Charles Close as Director-General of the Ordnance Survey.

We have noted with regret the announcement of the death of the following well-known scientific workers during the last quarter : Albert, Prince of Monaco ; Arthur Bacot, Entomologist to the Lister Institute ; Dr. J. René Benoît, Honorary Director of the International Bureau of Weights and Measures, Sèvres ; Dr. G. S. Boulger, botanist and geologist ; Prof. W.

Gowland, Emeritus Professor of Metallurgy at the Royal College of Science; Prof. W. Hallwachs of Dresden, best known for his work on photo-electricity; Prof. J. C. Kapteyn, For. Mem. R.S., the astronomer; Prof. O. Lehmann, of liquid crystal fame; Dr. W. H. R. Rivers, psychologist and anthropologist; Mr. F. W. Sanderson, Head of Oundle School; Ernest Solvay, the famous industrial chemist; Dr. C. W. Waidner, Head of the Heat and Thermometry Divisions, Bureau of Standards, U.S.A.; Dr. A. R. Willis, lately Assistant Professor of Mathematics at the Royal College of Science; Prof. W. Wislicenus, Director of the Chemical Institute of the University of Tübingen.

The Howard N. Potts gold medal of the Franklin Institute, Philadelphia, has been awarded to Prof. E. G. Coker, of University College, London, for his photo-elastic method of determining the distribution of stress in structural and machine members. Prof. Coker recently gave an account of the application of this method to determine the stresses produced in a material while it is being shaped by a cutting tool. The method is based on observations made on models constructed of transparent materials. Numerous tests have shown that the measurements made on models cut from transparent celluloid represent very accurately the stresses in metals. These determinations are made possible by the application of circularly polarised light, when a mere inspection of the projected image of the sample under test reveals at once the places under the greatest stress, and at which failure is most liable to occur. Side by side with the image of the model that of a piece of celluloid of the same thickness, but under definite load, can be projected. The load can then be varied to match the colours obtained in the different parts of the stressed model, from which the stress at the different points can be computed. The facts thus brought to light are of considerable importance in engineering, indicating at once the points of maximum stress and liability to breakdown.

The Commissioners of the Exhibition of 1851 have this year, for the first time, instituted Senior Studentships of the value of £400 per annum, tenable for a maximum period of three years, for students in this country instead of the well-known exhibitions awarded with such excellent results in previous years. The first award is as follows: Mr. A. E. Ingham (mathematics) and Mr. C. E. Tilley (geology), both of Cambridge; Mr. G. T. R. Hill (aeronautical engineering) of the University of London, University College; Mr. J. E. Jones (mathematics), University of Manchester; Mr. J. S. Buck (chemistry), University of Liverpool.

The scheme for the institution of a number of Fellowships to commemorate the work of the late Sir William Ramsay is now in full swing. The Trustees announced the award of no fewer than nine Fellowships at the end of July as follows: A Fellowship of annual value of £300 tenable for one year but renewable for a second year to Mr. R. W. Lunt, of the University of Liverpool, and of University College, London. Mr. Lunt will continue to undertake Chemical Research at University College, London, on Chemical Effects of Electromagnetic Waves over the Frequency Range $10^5$–$10^8$ cycles; the Glasgow Ramsay Fellowship of £300 to Mr. John Alexander Mair, of Glasgow University, who will continue his research on the Chemistry of the Terpenes; a special Fellowship of £300 for one year to Mr. William Davies, who has already held a Ramsay Fellowship for two sessions and whose work, especially that on the preparation of synthetic reagents from the toluic acids, shows special promise. The Danish Ramsay Fellowship has been awarded to Mr. Kristian Hoejendahl, of the University of Copenhagen, who will pursue his research in the University of Liverpool. Two Swedish Ramsay Fellowships have been awarded to Dr. J. O. G. Lublin, and Mr. A. W. Bernton respectively. Two Norwegian Ramsay Fellowships have been awarded to Mr. D. Nickelsen, who will work at the Imperial College of Science, and Miss Milda Prytz, who will work at University College, London. The trustees have placed at the disposal of the National Research Council of the United States of America a special Ramsay Fellowship of the value of £350, and Dr. Charles S. Piggot, of Baltimore, has been elected to the Fellowship. He will begin work at University College in October.

Dr. Ann C. Davies, of Royal Holloway College, has been awarded the Ellen Richards Research Grant of $1,000 from the American Association to aid Scientific Research by Women. The money has to be spent on the continuation of the research for which it is granted.

A great many donations and bequests for scientific, medical, and educational purposes have been announced during the last few months, mostly, of course, in the United States. Sir Jesse Boot has now given altogether £180,000 towards the cost and upkeep of the new buildings for University College, Nottingham, while another anonymous donor has given £100,000. These donations will make it possible to remove the whole of the academic work of the College to the new site, and, in addition, will provide the administrative accommodation required for the proposed East Midland University when it is established. Highfields Park, in which the new buildings are situated, was a gift to the city from Sir Jesse Boot. Queen's University, Belfast, received £50,000 from the estate of the late Mr. H. Musgrave, of Belfast, and the University of Glasgow £10,000 from Sir William Lorimer. Prince Albert of Monaco bequeathed 1,000,000 francs to the Paris Academy of Science. The dispute over the will of the late Mr. Amos F. Eno has now been settled. Columbia University receives $4,000,000 from the estate, and the American Museum of Natural History $272,000. This Museum has also received $1,000,000 from Mr. J. D. Rockefeller, Jr., and $250,000 from Mr. G. F. Baker, a New York banker.

During the last few years there has been a tendency in the United States to attach considerable weight to the results of psychological tests when selecting candidates for various posts, notably in the army during the war. It is now announced that the entrance examination for Princeton University will include tests of this kind. During a short experimental period candidates will be required to undergo them, but not necessarily to pass; later on, if the results are satisfactory, it is proposed to make success in these tests as essential as it now is in the written examination.

The unveiling of the medallion of the late Sir Norman Lockyer at the Observatory which he established in 1912 on Salcombe Hill, Sidmouth, now known as the Norman Lockyer Observatory, was performed on July 22 by Sir Frank Dyson in the presence of a large number of distinguished guests. The medallion, executed by Sir Hamo Thorneycroft, forms a striking portrait of the astronomer. It was presented by Lt.-Col. F. K. McLean, who assisted very materially in the original foundation of the Observatory, which is now under the direction of Major W. J. S. Lockyer. A leaflet issued in connection with the ceremony draws attention to the large number of important observatories in the United States founded and maintained by private donations. These include the Yerkes, Mount Wilson, Harvard College, Lick, Lowell, and Dudley Observatories erected and equipped at an aggregate cost of about £750,000. With such generous assistance it is not surprising that America now takes the lead in modern astronomical work. There are a number of small private observatories in this country, but no large, well-equipped observatory established and endowed by private people interested in the advancement of celestial science.

At the Annual General Meeting of the Institute of Physics held on May 23 Sir J. J. Thomson, O.M., was elected President of the Institute for the year commencing on October 1, 1922. In the course of his Presidential Address Sir J. J. Thomson, after dealing with the project to establish a Journal of Scientific Instruments, spoke of the present depression in industry, but he made the reassuring statement that out of 67 students who graduated with distinction in physics and chemistry in 1921, 46 had obtained suitable positions, while 14 were doing research work. He hoped that the series of Lectures on Physics in Industry which had been established would act to some extent as "Refresher Courses." Speaking of the difficulties which the Safeguarding of Industries Act had, in many instances, placed in the way of research, he characterised research itself as a "key industry," and he hoped that the Government would put every facility in the way of research workers being able to obtain without delay the apparatus they required. The Annual Report of the Institute stated that there were 408 Members, of whom 258 were Fellows.

The greatest heights reached by the members of the Mount Everest Expedition were 26,800 ft. by Messrs. Mallory, Somervell, and Norton, and 27,200 ft. by Messrs. Finch and Bruce. This latter ascent involved camping two nights at 25,000 ft. and the use of the oxygen apparatus. The height of the mountain is 29,000 ft. A final attempt to reach the summit on June 7 met with disaster; an avalanche struck half the party, and seven native porters were killed.

A new College of Tropical Agriculture is to be opened at St. Augustine, Trinidad, in October. It will be known as the West Indian Agricultural College, and aims at providing a three years' diploma course in tropical agriculture for those desirous of following the business of tropical planting; a shorter course for those unable to spare the time or money for the longer one, a special course of training for officials prior to their taking up tropical agricultural appointments, and special facilities for post-graduate research. The work will be carried on under Sir Francis Watts, who combines the duties of Principal of the College and Commissioner of the Imperial Department of Agriculture. Sir Arthur Shipley is Chairman of the Board of Governors and also the representative of Cambridge University. Lt.-Col. Sir David Prain is Vice-Chairman, representing the Secretary of State from the Colonies. Other members of the Board have been nominated by Glasgow University, the Royal Botanic Gardens, Kew, and the Imperial College of Science. Further details may be obtained from Mr. A. Aspinall, C.M.G., 15 Seething Lane, London, E.C.3.

We have received a letter from Messrs. Chapman & Hall, Ltd., drawing attention to the monographs in English issued by the Swedish Academy and dealing with the research work of some of their leading scientists. At the same time we received a copy of one of these monographs entitled, *The Homogeneous Electrothermic Effect*, by Carl Benedicks. It is well printed and illustrated, but with 117 pages and stiff paper covers the price is 15*s*. net. It is most unfortunate that it should be found necessary to make such an excessive charge for books of this description. The resulting sale must be extremely small, with the inevitable consequence that the attempt, now being made for the first time, to circulate these monographs in this country will be abandoned.

In the spring term of last year a series of eight lectures dealing with the present-day position of the leading sciences were delivered at King's College, London, and these lectures have now been published under the title, *Problems of Modern Science* (George H. Harrap, 1922. 10*s*. 6*d*. net). The subjects dealt with are Mathematics (Prof. Nicholson); Physics (Prof. Richardson); Astronomy (Mr. J. B. Dale); Organic Chemistry (Prof. Smiles); Biology (Prof. Dendy); Botany (Prof. Ruggles Gates); Physiology (Prof. Halliburton); and Anatomy (Prof. Barclay Smith). The lectures were intended for the general public, and, in book form, they are most admirably adapted to give those but slightly versed in scientific language a clear idea of the problems which modern research has suggested to us and of the results which have already been obtained. The story they tell is a very fascinating one, and the book should certainly find a place in every school library.

The British Association has just published a book dealing with the history of its formation and work during the last ninety years (*The British Association: a Retrospect*, by O. J. R. Howarth, pp. 318, with 11 portraits and other illustrations. Burlington House, 1922). The Association owed its formation to Sir David Brewster and John Phillips, the secretary of the Yorkshire Philosophical Society, aided by Sir John Robinson, Prof. Johnston, J. D. Forbes, Vernon Harcourt, and Sir Roderick Murchison. It was modelled on the lines of the Deutscher Naturforscher Versammlung, a society originated by Prof. Lorenz Oken, of Jena, at Leipzig in 1822. The first meeting of the English Association was held at York in 1831, Viscount Milton, President of the Yorkshire Society, being in the chair; in 1832 the members met at Oxford, and in 1833 at Cambridge. A reproduction of a sheet of signatures collected at this meeting contains the names of some of the most famous men in the history of English science: Faraday, Brewster, Forbes, Adam Sedgwick, William Smith, Whewell, and others. For some years after its formation the Association met with much opposition and ridicule, notably *The Times* newspaper (hence Palmerston's consolatory remark to Murchison, "Never mind them; a man who is not *Times* proof cannot succeed in life!" This in 1846). Dickens's crude satire, "The Mud-fog Papers," first published in *Bentley's Miscellany* (1837–9), is probably, however, the best-known. In quite early days the difficulty of balancing the scientific and holiday aspects of the meetings was apparent. After the 1831 meeting it was considered advisable not to arrange papers or lectures in the evening after dinner. In 1837 Sedgwick wrote:

> "Let me, then, transport you to Liverpool, among mountains of venison and oceans of turtle. Were ever philosophers so fed before? Twenty hundred-weight of turtle were sent to fructify in the hungry stomachs of the sons of science. Well may they body forth, before another returning festival, the forms of things unknown! But I will not anticipate the monsters of philosophy which such a seed-time portends. The crop no doubt will be of vast dimensions."

Murchison's writings gave a similar impression of good feeding. Edward Forbes seems to have been a leader of the picnic party. He arranged a dance in the Assembly Rooms, Edinburgh, in 1850, to Brewster's great disgust, and previously in 1839 had founded the Red Lion Club, of which it is said: "... Their chairman became the Lion King; new members, on admission, became cubs; the organisers of the arrangements, jackals. On rising to speak (or otherwise to entertain the company) they must roar and flourish their coat tails as an introductory ritual. . . ." It is indicated that this club is still in existence, but presumably with a revised constitution! For all this, the convivial spirit has not played a large part in the history of the Association. Its record of work is a magnificent one, and it has been carried out almost entirely from the subscriptions of the members. Large donations have been surprisingly few; so few, indeed, that they can be mentioned here in their entirety: 1903, Sir Frederick Bramwell, £50, for a lecture to be delivered in 1931 on prime movers; 1912, Sir James Caird, £10,000; 1913, Sir James Caird, £1,000 for radio-active research; 1922, Sir Charles Parsons, £10,000. There was, in addition, a fund, privately subscribed in 1919, to enable the Association to continue its grants during the period immediately following the war. The expenditure on grants to scientific investigations totals £83,000, including £12,000 spent on Kew Observatory, £1,000 on Electrical Standards, £2,600 on Seismological Investigations, £1,370 on a Star Catalogue, £3,800 on the Table at the Zoological Station, Naples, £2,600 on Cave Exploration, etc. Mr. Howarth is to be congratulated on the valuable and interesting book he has compiled from what must have appeared most unpromising material. His "Retrospect" surveys a very important part of the scientific work of last century, and he tells us something about a very large number of its great names.

We have received from the Controller, H.M. Stationery Office (Imperial House, Kingsway, W.C.2.), the Report of the Inter-departmental Committee on *The Methods of dealing with Inventions made by Workers aided or maintained from Public Funds* (price 6*d*.) ; the first report of the *Adhesives Research Committee* (price 4*s*.) and a report from the Fuel Research Board dealing with *Tests on Ranges and Cooking Appliances* (price 2*s*. 6*d*.). The general tenor of the report of the Inventions Committee can be gathered by the general principle laid down, *i.e.* that when a research worker is employed by the Government and is provided with equipment and accommodation at the cost of the State then the invention is the property of the State and the reward to the inventor (either by way of a money grant or of a share of patent rights or otherwise) should be increased or diminished in proportion to the remoteness or proximity of the invention to the work for which he was engaged or for which he had special facilities or knowledge as the result of his employment.

It is recommended that all questions relating to inventions by Government servants be referred to an Inter-departmental Patents Board, which should take over the whole of the present work of the Royal Commission on Awards to Inventors so far as inventions by persons in Government employ are concerned. It is further suggested that the development of such patents be entrusted to an Exploitation Committee consisting partly of officials and partly of business men willing to assist in the work. It is recognised that the success or failure of the scheme would hinge on the personnel of the Patents Board, and it is recommended that this board should not comprise any representatives of the Treasury or the Department in which the inventor is working, but should be composed of impartial persons (lawyers or men of distinction in science or commerce) with an experienced chairman.

The report of the Adhesives Research Committee contains an account of a number of experiments that have been made on methods of preparing and testing glues of various sorts together with a long monograph on Gelatin by Dr. Slater Price, who has used some of the material in an article which he has written for Science Progress. The report on cooking ranges is based on a large amount of experimental work carried out under the direction of Mr. A. H. Barker, Lecturer in Heating and Ventilating Engineering at University College, London. The outstanding result is the extraordinarily low efficiency of such stoves. The heat supplied through the hot plate and oven represents only from 5–10 per cent. of that given out by the fuel which is burnt—all the rest is lost as far as cooking is concerned. This small efficiency is due in part to bad design of existing types of ranges and partly to the fact that when a fire is lighted the heat is distributed to a large number of parts which are not required. It is not possible to heat the boiler *alone* or the oven *alone* or the hot plate *alone*, although only one of the three may be needed. Until this can be done the domestic coal cooker must remain an exceedingly inefficient appliance. Turning to the present-day type of range, it was found to be important to exclude leakage of air into flues and oven, thus cleaning doors, rings, etc., should fit properly. Also to enclose the fire itself as completely as possible so that air should only have access through the grate bars. It is also important to line the door of the oven and the iron plates on top and in front of the stove with non-conducting material. Finally the oven, fire, and flues should be so arranged that the flame gases *first* pass under the oven and then over it.

A large number of very practical tests were made on ranges of different types—including the cooking of a dinner. The results showed that, while it was possible to perform a standard series of operations by burning as little as 7 lb. of coal in a specially designed range, the ordinary article cooked required about 21 lb. It is difficult to make a fair comparison between the cost of heating by gas stove and by coal. Oven cookery costs about the same by both, but hot-plate work is dearer with gas, and when large quantities of hot water are required (*e.g.* for baths), or a continuous supply, no gas appliance can be really economical. It appears that only one-third of the heat supplied by the burning gas is used in a gas cooker, *i.e.* when the cost of gas is one shilling per therm as supplied by the company, each therm of heat actually used costs about three shillings—the rest is lost by inefficient design of the cooker. It should be possible to improve this design so that half the heat developed by the combustion of the gas is usefully employed.

It is not generally known that Dr. E. H. Hankin, whose article on the Mental Ability of Quakers and reply to criticism thereon are published in this and a previous number of SCIENCE PROGRESS, was the discoverer of a method of dealing with cholera on the large scale which is now in fairly general use in India and has probably saved a large number of lives. Many years ago he found that the growth of cholera vibrios in wells can be checked by destroying the organic matter in the well-water by throwing in a little permanganate of potash. We believe that Dr. Hankin has had no sort of recognition of any kind from any government or academical body for this fine addition to the armoury of hygiene—except the Kaisar-i-Hind medal. He is not a medical man, but as Government Analyst in the United Provinces was one of the first to introduce bacteriology into India at a time when that science was scorned by all the authorities of our Indian Empire, so that even Koch's discovery of the cholera vibrio was utterly neglected. Hankin's work has been of greater importance to India than the work or no-work of many persons who have received more honours and acknowledgments. Really, in some respects the British remain barbarians to the present day, and he should write an article on the mental ability of the Indian Powers-that-Be!

# CORRESPONDENCE

## HANDBOOK OF METEOROLOGY

I. *From* J. W. Redway, Meteorological Laboratory, Mount Vernon, N.Y.

*To the Editor of* Science Progress

Dear Sir,—A review of my *Handbook of Meteorology* contains the statement, "The causes of precipitation are less clearly set out." If you have formed this opinion I certainly am glad to know it, and I appreciate your frank statement; for it is only by taking advantage of such opinions that weak places can be strengthened.

So far as cloudbursts are concerned, I plead guilty. If only I could obtain definite knowledge in the problem I might make myself clear. But my experience of a dozen years in a region where cloudbursts come when they come has forced me to object to theories that have been advanced. One meteorologist of highest repute calls the cloudburst "an exaggerated thunderstorm precipitation." This might apply to the downpour of a thunderstorm in the eastern part of the United States, but certainly not to the cloudbursts of the western border—Arizona or California.

The first note on p. 105 records my own experience—and that very mildly. To the best of my judgment more, rather than less, than 6 inches of water came down in sheets. The fact that I wish to emphasise is, that all the water vapour up to cloud-height limits could not have accounted for the amount of water that fell. A light drizzle continued for several hours; there was a very light fall a few miles away, but none at all across the range.

Now, if someone will propound a theory of cloudbursts that will conform to my experiences I will endeavour to express it in a style that will convey a clear meaning.

Thanking you for your note, I am very sincerely yours,

J. W. Redway.

Mount Vernon, N.Y.
*May* 31, 1922.

II. *From* E. V. Newnham, D.Sc., Meteorological Office, London

*To the Editor of* Science Progress

Dear Sir,—In the review in question it was not my intention to suggest that cloudbursts are sufficiently well understood for it to be possible to give a clear and concise description of the way in which the heavy rainfall is brought about. Mr. Redway's remark, however, on p. 105 of his *Handbook*, that "All the water in an overhead saturated air at a temperature of 70° F. over the area covered by the downpour would not make a rainfall sufficient to account for the water dropped by a cloudburst," makes me wonder whether he has not overlooked the possibility of such exceptional precipitation being a result of strong local convergence of air currents. In the case described on p. 105 the duration of the rainfall was about 15 minutes, and it seems not unreasonable to suppose that during this period the upper winds may have caused the air from a considerable region to ascend over the place in question and produce there a total fall far in excess of the amount of water suspended overhead at a particular moment. For an interesting example of this kind of phenomenon I will venture to refer Mr. Redway to my "Report on the thunderstorm which caused disastrous floods at Louth on May 29, 1920" (Air Ministry, Professional Note No. 17, H.M. Stationery Office, London). I would not suggest that cloudbursts in America can necessarily be explained on these lines, but until there is clear evidence to show that the normal causes of rainfall are inadequate, it seems to me unnecessary to call in the agency of waterspouts, unless of course there is some direct evidence that they play a part—such as would be furnished by the invariable appearance of waterspouts previous to the occurrence of a cloudburst, in places, moreover, to windward of the subsequent cloudburst.

The chapter on Precipitation appears to me incomplete in that there is no description of the mode of formation of extensive rain areas of the kind that occur in front of cyclonic depressions in temperate latitudes, notwithstanding the excellent papers on this subject that have been written by V. & J. Bjerknes in recent years (a very good example of Norwegian research in this subject is furnished by J. Bjerknes and H. Solberg's "Meteorological Conditions for the Formation of Rain," *Geofysiske Publikationer*, vol. ii, No. 3. An abstract of this work appeared in SCIENCE PROGRESS for July 1922.

E. V. N.

*July* 16, 1922.

## THE BANTU RACES

*From* DR. H. F. SHELDON

*To the Editor of* SCIENCE PROGRESS

DEAR SIR,—In No. 64 of SCIENCE PROGRESS for April 1922 it is stated, on the top line of page 571, by Mr. A. G. Thacker, that the Bantu races reached South Africa after the white man.

J. A. Mitchell has shown that there is evidence that typhus has existed among the natives of South Africa for many years—they are quite familiar with it under the name of Ifiva Mnyama, or Black-tongued Fever—and about a thousand cases a month are now known.

Considering the prevalence of typhus before the last century, it would be very unlikely that Whites did not introduce the disease to South Africa.

The Bantu is inclined to blame the white man for intruding into his peaceful home and for infecting him with typhus.

The statement of Mr. Thacker would indicate that the Bantu asked for trouble in displacing the Bushman. Are there any parallel records of the position of the Whites and Bantu from the earliest times?

In addressing the "Bunga," or native parliament, on the subject of typhus I quoted Mr. Thacker's statement that the Bantu was a later comer to S.A. than the white man, but encountered considerable scepticism.

The point is, what is the exact meaning of "S.A." as used by Mr. Thacker?

Yours, etc.,

H. F. SHELDON.

Umtata, South Africa,
*May 23rd*, 1922.

## THE MENTAL ABILITY OF THE QUAKERS

*From* Dr. E. H. Hankin

*To the Editor of* Science Progress

Dear Sir,—Principal Graham's letter in your July number suggests that he is under the impression that my article on the above subject was meant to be an attack on certain Quaker customs. My intention was the exact contrary. It seems to me to be probable that the quasi-rational customs in question were of positive value for the following reasons.

In a small book recently published by me entitled *The Mental Limitations of the Expert,* it is pointed out that we have two methods of coming to a decision: one by means of conscious reasoning—a process that may take a long time as it needs numerous data that must be available to consciousness; the other method is an intuitive mental process that almost instantaneously leads to correct decisions. The latter process is especially used by business men, and this power forms a large part of what is popularly known as the "business instinct." For instance, a merchant once said to me that the chief part of his business consisted in arriving at important decisions at 10 seconds' notice. On relating this to a clever company promoter, he replied, "So do I, but I only take 1 second." "Isn't that," I asked, "due to some activity of the subconscious mind?" "I don't know that word," said he. "I call it higher mathematics." This reply illustrates the singular capacity for profound ignorance that so often characterises the successful man of business. In practice most people, on most occasions, use the two processes at the same time combined in different proportions, but it may generally be noticed that those who rely most on sudden intuitive decisions are least capable of reasoned argument. That there is some kind of antagonism between the two processes is indicated by Lord Mansfield's advice to a friend to judge according to his notions of common sense. "But," said he, "never give your reasons. Your judgments will probably be right, but your reasons will certainly be wrong." Lord Mansfield's friend was not an expert. The expert, in his work, has to give reasons and they have to be good reasons. With some experts the power of intuitive decision seems so little developed that they are ignorant of its existence.

Certain grounds are adduced in my book for suspecting that our education, by attempting to develop precociously the power of conscious reasoning, actually thereby checks the development of the intuitive powers of the mind. Grounds are given for suspecting that, in order to stimulate such development, what is wanted in education is formal discipline rather than attempts to directly stimulate the intelligence. But the proof of the pudding is in the eating. Can a body of men be pointed out who, by their creed, their social habits and their education, have discouraged reliance on conscious reasoning and, if so, what was the effect on their intuitive mental powers? An answer to this question is given by my study of the Quakers. At the time of their origin and in the immediately succeeding years they showed an extraordinary development of business capacity. Further, this business capacity appears to have been inherited. Either it was really inherited or there was something in the mental habits and education of the Quakers that, in each generation, stimulated the development of the intuitive powers of their minds. In considering what this something can have been, we must first ask how may we expect it to be possible to artificially stimulate such powers?

In the first place most, if not all, mental capacities can be improved by practice. It is probable that this is the case with the business instinct, for we find this most developed in those who, in their daily work, have to come to sudden decisions. Secondly, in view of the apparent antagonism between the habit of conscious reasoning and intuitive decision, we may suspect that a mental regimen that discourages reliance on such reasoning may aid the growth of the intuitive capacities of the mind. The question therefore arises whether such tendencies and discouragement of reasoning were encouraged by the Quaker faith ? There can be no doubt that this was the case in a remarkable degree.

Their mental habits certainly gave practice in coming to decisions without conscious reasoning. For instance, if a Quaker had to decide any important matter, instead of reasoning about it, he would pray and then wait for divine guidance. From the secular point of view, what then happened was that an impulse came from the part of the mind outside consciousness and on this impulse he acted. Thus he had practice in arriving at intuitive decisions as a religious duty. An apparently trivial custom in Quaker families, both in England and in America, was that children were never allowed to change their minds. If they said they wanted cake they had to have cake. They were not allowed to change their mind and ask for jam. This custom must have tended to practise them in arriving at definite conclusions. Other examples are given in my paper of discouragement of reliance on conscious reasoning in Quaker society.

Religious teaching and influence must have played a large part in the mental development of the Quaker child, and in looking for causes of their business ability we must see whether this also may not have had some effect. It led to the use of formal discipline probably to a greater extent in Quaker schools than in those of other Christian sects. For instance, they used such books as the *Academia celestis* and Robert Barclay's *Apology*, books which must have been of phenomenal dullness to children, instead of various Latin authors hitherto in use. The frame of mind inculcated by religious teaching, by leading the child to rely on supernatural authority rather than on reasoned explanations of the phenomena of nature, was likely to cause a beneficial delay in its use of conscious reasoning. But a far more important effect that may be expected from religious influence in early life is that it supplies a non-rational or unreasoned basis for moral character. A reasoned sanction for conduct tends to be weaker than a religious sanction because it is liable to be attacked and upset by reason. But if a child is taught a morality based on something in which conscious reason plays no part, if his morality is based on an unreasoning fear or love of something that is beyond his comprehension, then he will acquire, not reasons, but prepossessions in favour of being good and against doing ill. Against such prepossessions, if sufficiently deep-seated, " profane reason " will be powerless. How can such prepossessions be best produced ?

A religion that is rational from the point of view of the child and that can be taught in a way that will stimulate his intelligence is possible. " There is no God but God. Let us loot the unbelievers," is a reasonable creed. " There is no God but God. Let us give money to the poor," is, at first sight, much less rational. To the untutored mind of a child, if he reasoned about it, it might appear as a *non sequitur*. A paradise full of worldly pleasures is a reasonable proposition. A paradise that offers nothing but religious ecstasy is a far less reasonable idea. But the creed that offers material advantages both in this world and the next, from being good, is far less suitable than the other for producing moral prepossessions. An impulse to be moral may be produced thereby, but it will be based on conscious reasoning, and will therefore remain in that part of the mind where it is exposed to such attacks of reason as usually precede a fall from a state of grace. The religion taught to a Quaker child was entirely different in its plan. A book in my possession, written in the year 1851 by a Quaker lady and entitled *Mama's Bible Stories*, well illustrates this statement. The book contains traces of the custom of human sacrifice, of taboo and of fetish, and the conception of the Deity may well date from Neolithic times. Throughout the book there is bad reasoning combined with admirable morals. Practically no motive is given for moral conduct except that it is pleasing to God. The moral sentiments in the book are never reasoned. They are mentioned incidentally. Their correctness is taken for granted. That they are beyond reason is indicated by the fact that the Deity is represented as having a standard of conduct far different from that demanded of His followers. Hence there is nothing in the morals likely to arouse reasoning on the part of the child and thereby cause them to stick in his consciousness. They are therefore likely to pass beyond it to the parts of the mind that are outside consciousness or conscious reasoning and thus give rise to moral prepossessions. This appears to be a valid reason why such teaching of religious dogma is of value, and why it is more valuable the more it disregards the use of sensible reasoning.

Moral character based on prepossessions seems to have another use besides making us moral. If making us moral was the sole function of moral system, the argument in the previous paragraph might not be sufficient for distrusting a morality based on reason. Indeed, it might be asked why sensible people should not make their interests their standard of conduct. This has been done in recent years to a large extent by the Germans. It has been followed by, and apparently has been the cause of, a singular defect in their reasoning powers. In such widely different fields of mental activity as commerce, diplomacy, and the conduct of war, their reasoning power has shown itself singularly short-sighted and also has exhibited a remarkable preference for the more devious or the more brutal of two alternatives.[1] These features of the German mentality have only developed in recent years *pari passu* with the loss of religious influence in their education.[2] The Germans are influenced by the evidence that is immediately under their noses, but they fail to be influenced by that effect of accumulated earlier experience that may be designated as common sense. Hence their conduct has often been in contradiction to their real interests. Leaving fact for theory, it seems that what happens is that their reasoning process is cut short by the intervention of some selfish or brute feeling. We all have in our minds such feelings. In normal minds they are balanced or inhibited by moral prepossessions, and therefore they fail to cut short the reasoning process and we arrive at well-balanced conclusions. The example of German mentality suggests that a morality based on reason is less capable of inhibiting our selfish nature than one based on unreasoned prepossessions.

Principal Graham, in his letter to you, asserts that the strength of the Quakers in business, etc., lay "in their reverence for human beings as the only holy Temples where the divine dwells." That neither this nor any other purely religious influence was the source of their capacity in business is rendered probable by the fact that they showed high business ability during what a Quaker authority describes as "the darkest period in the history of the sect,"[3] when what Principal Graham designates as "temporary fads" formed perhaps the predominating part of their creed, that this dark period was brought to an end by a revival due to the preaching of Stephen Grellet and William Forster between 1810 and 1820,[4] that thenceforward the Quakers

[1] See "German Business Methods in the United States," by H. C. Burr, *Quarterly Review*, July 1919, p. 16; *Ourselves and Germany*, by Dr. E. J. Dillon (London, Chapman and Hall, 1916); and *Britons versus Germans in China*, by Dennis K. Moss (Hongkong Daily Press, 1917).

[2] See *After the Day*, by Hayden Talbot (London, Herbert Jenkins, 1920).

[3] *Religious Societies of the Commonwealth*, by R. Barclay (London, Hodder & Stoughton, 1876).

[4] *Life of the Right Honourable William Edward Forster*, by T. W. Reid (London, Chapman & Hall, 1888).

gradually dropped their peculiar quasi-rational social customs and that thenceforward their ability in business seems to have been less marked.

Principal Graham asserts that the lack of business ability in the Mennonites is unexplained. It is unexplained on his theory for, as stated in my article, their religious creed was almost identical with that of the Quakers. Like the Quakers they had abstemious habits. They were honest. They apparently lacked the advantages of university education, and they were subjected to persecution. Their lack of business achievement, on the contrary, is explained on my theory as they appear to have been nearly free from the quasi-rational social customs that characterised the Quakers.

The sudden development of business ability in the Quaker community is a remarkable fact. That their mental habits should be followed by such a result is in accordance with the thesis developed in my book. But there can be little doubt that there is room for further research as to the exact manner in which their peculiar mental habits were operative in producing such an advantageous result.

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# ESSAYS

## FROM MYTH TO SCIENCE (Joshua C. Gregory, B.Sc.).

THERE is a familiar story of a countryman visiting the Zoo for the first time. After staring at the giraffe in astonishment mingled with horror, he exclaimed, "There ain't no such animal!" We can hardly sympathise with this countryman over the giraffe, which is too familiar to be doubted, but we are staggered from time to time when science draws for us a new portrait of some prehistoric creature. We feel occasionally, in a gallery of prehistoric monsters, like the countryman at the Zoo. Polite incredulity, at the least, seems most fitting when a creature more than forty feet long, even if its length is mostly neck and tail, is said to have behaved like a hen and laid eggs. If we were removed to a desert island where only men lived, deprived of our memory of all other members of the great community of life and then suddenly introduced into Noah's ark, we would shrink in terrified horror from a world so apparently alien to our own. The extraordinary diversity of animal species, even now, when familiarity momentarily disappears in contemplative reflection, suggests a mingling of many worlds instead of a world which is really one. If we could see, in succession and for the first time, a jelly-fish, a sea-urchin, a lobster, a tortoise, an eagle, a shark, a giraffe, a butterfly, a whale, an ant, an armadillo, an elephant, and many others, we should agree with the old opinion that each species was specially and separately created, and add that many different worlds must have been shuffled together.

Yet the world of life, with all its diversities, is one family. The doctrine of transformism, the doctrine that all species have grown out of other species, is too well grounded to be refused. Mr. Balfour, in a presidential address to the British Association, spoke of the æsthetic thrill which the insight of science into the unities of the universe often bestows upon us. The concept of evolution, of transformism, the affirmation that one continuous process of development has produced the myriad forms of life gives such an æsthetic thrill as we realise that all the infinitely varied creatures around us are united as the roots, trunk, branches, and foliage of a tree are united. Thomas Fuller found in the genealogy of his Saviour that "Rehoboam begat Abiam; that is, a bad father begat a bad son. Abiam begat Asa; that is, a bad father a good son. Asa begat Jehosaphat; that is, a good father a good son. Jehosaphat begat Joram; that is, a good father a bad son." One fundamental plan, one common relation of parentage, ran through many different situations. So in the world of life many species, at first sight so diverse as to belong to different worlds, are manifestations of one fundamental plan.

The world of the human mind, when surveyed as the various animal species are surveyed in a museum, produces the same impression of a bewildering collection of beings brought into a world to which they do not really belong. "The phenomena which early societies present us with are not easy at first to understand," remarks Maine, because they are so strange and uncouth.[1] The beliefs and practices of our primitive forefathers,

[1] *Ancient Law*, 4th ed., pp. 119–20.

as of our primitive brothers to-day, often seem to us as strange, uncouth, and alien as the strange beasts which once peopled the earth.

Though the "phenomena which early societies present us with" are difficult to understand at first, Maine thinks they become "few enough and simple enough" to patient thought,[1] but Sir James Frazer insists that "the savage does not understand the thoughts of civilised man, and few civilised men understand the thoughts of the savage."[2] Now this mental separation between primitive and civilised men may be compared to the biological separation which divides species of animals like the elephant and the ant. The philosopher Reid thought that the differences between human minds were greater than any other differences between members of the same species: all swallows, or even all queen, worker, or drone bees, are more alike than men are alike mentally.[3] He might have gone further and suggested that men are divided into mental species as the animal world is divided into biological species. For if we consider the mental differences between men who, widely speaking, are on the same level of civilisation and the mental differences between men on different levels we must agree with Marett that "human nature, whether savage or civilised, is subject to perpetual transformation."[4] Evolution first expended its creative impetus on a variety of biological forms—producing, for example, mammals with their skeletons inside and animals who, like crabs, have their skeletons outside. This "perpetual transformation" was transferred from the body to the mind when man appeared and divided him into mental species as his animal predecessors had been divided into biological species. The modern young lady who startles her Victorian grandmother is a latest product of the continuous alteration which, as the generations pass, strews mental types along the route of life as biological types were strewn in the past. Lecky remarks that civilisation usually destroys opinions by making them obsolete.[5] History preserves these obsolete opinions as a museum preserves extinct animals, to remind us that there are mental as well as biological species. The men who tortured witches and the judges who condemned them were mentally different from their successors who relegated witchcraft to the limbo of superstitions. As biological difference intensifies with retreat down the scale of life, so mental contrasts are sharper between primitive and civilised man than between successive generations or centuries. When we enter the primitive world we live with men and women who are different from ourselves, as different in thought, deed, in custom, as they were in speech.

We enter this primitive world through the portal of the fairy-tale. Fairy-tales, excluding modern stories, are selections from the myths and legends which contain beliefs and habits of life once prevalent. They may be compared to modern novels, though the resemblance is not complete. A modern novel combines incidents, beliefs, customs, fashions, and estimates of life which are characteristic of its period into a dramatic form or story. It may not be direct transcript, it may twist realities into dramatic form, but it reveals the life of its time. The fairy-tale does the same thing. Now the personages of the fairy-tale do not think or act as we do, and so different are they from us that they seem to live in a different world. The fairy-tale seems merely to devise entertainment because it treats our incredibilities as credible. But primitive people still among us guarantee its estimates

[1] *Ancient Law*, 4th ed., pp. 119–20.

[2] Quoted by Cardinall: Preface to *The Natives of the Northern Territories of the Gold Coast*.

[3] *An Inquiry into the Human Mind*, ch. i, §1.

[4] *Psychology and Folk-lore*, p. 14.

[5] *Rise and Development of Rationalism in Europe*.

of possibility as the real estimates of the past. Helpful animals are prominent personages in the fairy world, and they can often help more effectively than human beings. Gold Coast natives to this day think that animals can talk and understand human speech. Every Gold Coast man has some animal—it may be a crocodile, a python, a squirrel or even a mouse—which is his brother and helper.[1] The pagan tribes of Borneo have secret helpers who reveal themselves under animal forms in dreams.[2] A beast in the fairy-tale is an enchanted prince who recovers his shape. Belief in metamorphosis is a fixed, universal, and dominating belief among primitive peoples which has left its impress upon the old legends of the world. Early men's estimates of the animal sharply divided their mental life from ours. They traced their descent to animals, they ascribed to them supernatural powers, they feared their magic and they were protected by them. The first chapter of Genesis draws one dividing line in the development of thought. The creation of man is there carefully separated from the creation of lower animals and his superiority is explicitly affirmed. This marks a reversal of estimate. Durkheim notes that the humbler natural objects, including animals, are the first to be divinised [3] and, according to Wundt, in the totemic age of human history the relation of animal to man was the reverse of that relation as it is estimated to-day.[4] The vanished reputation of the animal survives in one great personage of myth. The dragon, who may be taken as one personage with many appearances, embodies the original impression of dread, magical power, and eminency which the animal made upon the primitive mind.

Since the mind is an organised system, a difference at one point implies differences at others: a Bolshevist and a believer in the Divine Right of Kings have different minds. Men who thought of the animal as primitive men thought of it must have thought of the world differently from us. They and we form different mental species, as lobsters and swallows form different biological species. In Chaucer's *Canterbury Tales* the poet collects into one company many different people, as Noah collected many different animals into one ark. Blake says of these characters: "Some of the names or titles are altered by time; but the characters themselves remain unaltered; and consequently they are the physiognomies or lineaments of universal human life beyond which nature never steps." This obscures one truth by over-emphasis on another. "As one age falls another rises different to mortal sight," but scarcely "to immortals ONLY the same." The "same characters" are "repeated again and again, in animals, vegetables, minerals, and in man," but is it true that "NOTHING new ever occurs in identical existence"? [5]

There are mental species as there are biological species, and as evolution has spread many different animal forms through nature, so it has spread many different forms of mind through human life. There is underlying connection and even underlying identity—Blake strikes one truth, though he somewhat obscures another. There is a fundamental unity which connects living species together through evolution, and there is a fundamental unity which evolves all men's minds as essentially one family. The unity of human thought has many aspects; of these aspects one fundamental method of mind is here selected for discussion.

In an Australian camp some native men were enraged at another. They

[1] Cardinall, *The Native Tribes of the Northern Territories of the Gold Coast*, pp. 37–9.

[2] Hose and McDougall, *The Pagan Tribes of Borneo*.

[3] *The Elementary Forms of the Religious Life*, Swain's trans., bk. I, ch. iii.

[4] *Elements of Folk Psychology*, Schaub's trans., Preface.

[5] *Prose Fragments*.

placed a stick to point towards his hut and sang over it to fill it with magic power. Messrs. Spencer and Gillen, who describe the incident, say that when the victim knew of the magical pointing-stick he went to bed in terror. They tried every means of reassuring him: they laughed at him, they reasoned, they scolded, they coaxed, they even beat him. But everything failed and in twenty-four hours the man was dead.[1] His camp-mates thought he was killed by magical power directed by the stick—this was their interpretation of his death; we say unhesitatingly that he died of fright—this is our interpretation.

When a woman who is suckling a child dies in Paraguayan Chaco, her child is buried alive with her. The Chaco Indians fear she will return to claim her infant if it is not laid in her grave. Mr. W. Burbrooke Grubb, a missionary in Chaco, persuaded his people, on one occasion, to save a child who had been thus doomed. During the night after the funeral a wild uproar filled the camp: a woman had seen her dead friend enter her tent. The dead woman had come for her child—this was the interpretation in Chaco; a woman who feared the breach of a funeral custom had dreamed of her dead friend's return—this was the missionary's interpretation.[2]

A savage who happened to make good hunting when he was carrying a ham-bone took one with him on all his future hunts. He mistook, in our opinion, a mere coincidence for a magical connection.[3]

These differing estimates of the same incidents depend upon the rôle of interpretation in all judgments. A little reflection shows that this interpretation is very extensive and very pervasive. When we see water we know it can wet us: this is an interpretation, for wetness can be felt but not seen. We interpret one another's thoughts by words or gestures; we interpret one another's actions by constructing a context for them—assuming, for example, that a lady entering a confectioner's will buy a cake; we interpret the events of nature in a precisely analogous way—concluding, for example, that clouds have been charged with electricity when lightning flashes. We are never content with what we actually see or hear or touch, or experience generally, but always construct, sometimes spontaneously, sometimes deliberately, a context, a larger whole, in which to set our experiences. Thus, behind the world of actual sense, behind its colours, shapes, sounds, smells, and "feels," science supposes a world of minute particles—molecules, atoms, or electrons. Scientific theories are simply wide, palpable extensions of the interpretive habit which dominates our minds. Our simplest experiences contain some interpretation, though careful reflection may be needed to discover it. When we try to piece together the clues in a murder trial we are obviously constructing a context, placing the death which we know in a wider whole. In scientific theories or hypotheses ample contexts are provided for experiences: a system of moving particles and ether waves is constructed around the colours we perceive.

In our interpretations one thing is compared with another thing which serves as a model. A girl of thirteen asked her uncle, who lectured in a university, whether staff and students assembled each morning for prayers. Universities might be no worse for regular morning prayers, but their arrangements forbid. The girl knew that boys and girls study in schools and older people in universities; but when she argued from morning prayers at her own school to morning prayers at a university, she assumed a school to be a more perfect model of a university than it is. Her error revealed her method of interpreting through models, and her elders use the same method though experience makes them more circumspect in applying it. When we assume

[1] *The Northern Tribes of Central Australia*, ch. xiv.
[2] *An Unknown People in an Unknown Land.*
[3] Carveth Read, *The Origin of Man and of His Superstitions*, p. 116.

that a neighbour's gong means dinner, we judge by our own habit or by someone else's, and in this and in more complex instances the method of comparison with models works truly, though, in spite of circumspectness, it often works wrongly.

Now the primitive mind resembles the civilised in having a fundamental interpretive habit. It resembles it in constructing contexts or larger wholes to fit to its experiences, and it resembles it in using certain models of reality for making these constructions. Science has prospered by corpuscular constructions: it has succeeded in interpreting the world by supposing bodies to be composed of very minute moving particles. The corpuscle is obviously, in the first instance, a speculatively attenuated gross body —a marble looked at through the wrong end of a telescope. The world of gross bodies, separated from one another and moving in space and time, is obviously the primary model of the corpuscular world constructed by science to provide a context for the world of sounds, colours, and the like —the world as it appears to us. The primitive mind differs from the civilised because it constructs a different context for the world as it appears to us and uses different models of reality for these constructions. Speaking generally and ignoring qualifications which are irrelevant in speaking generally, the primitive has, presumably, the same direct experience of the world as the civilised man: he sees, hears, smells, and feels as the latter sees, hears, smells, or feels; he sleeps, eats, is hungry or thirsty, loves, hates, has pain or pleasure, dreams or dies in the same way. This fundamental core of experience and the fundamental habit of constructing contexts based on models of reality connects all human minds into one great family. So, in a wider sense, a common participation in one fundamental life connects all animals into one great group. Different biological species arise as different manifestations or forms of a common life. So primitive and civilised minds divide into mental species, because they construct their contexts for experiences so differently and favour different models of reality. "The Cherokees give their children a concoction of burs to strengthen their memories; for as a bur will stick to anything, the mind of a man with a bur inside him will cling to all kinds of useful information."[1] The Cherokees, the Australians who slay with charmed sticks, the Chacos who bury living infants with their mothers, and savages who believe in the magic of ham-bones, have different minds from civilised men, as lobsters, snakes, and giraffes have different bodies.

A small boy who delighted in pulling switches thought they were bells which summoned a fairy who put on the electric light. This hypothesis, prompted, perhaps, by reminiscences of Tinker Bell, gratified his sense of fitness or reality and, since pulling switches did light rooms, conducted him to success. Events did happen AS IF a switch were a bell, AS IF a fairy answered it and AS IF she sent the light. Erroneous hypotheses can work, though they ultimately fail to meet the growth of demand upon them. The same "as if" appears in all interpretation, whether it be in a primitive belief or in a modern scientific hypothesis. Substances combine together and behave AS IF they were composed of atoms; an Australian native dies when a charmed stick is pointed at him AS IF the stick had been endowed with magical power. This "as if" connects the experiences interpreted with the model which supplies the method of interpretation. Now the Tinker Bell model was as congenial to primitive men as it is still congenial to the child. The primitive model of causation or effectiveness is human action or thought: all things are explained by reference to the doings of living beings who are either human or obviously modelled on human beings. The animal actors in primitive myths are men, or supermen, in animal form. The primitive mind explains, to put it concisely, by telling a story.

[1] Carveth Read, *The Origin of Man and of His Superstitions*, p. 330.

Adequate explanation or interpretation depends upon adequate realisation of alternatives. On the top of Pen-maen-mawr there is a group of three huge stones which are huddled as if they had been dropped from above. During part of last century science could not suggest a reasonable interpretation of this appearance. In Shrewsbury there is an "erratic" boulder called the "Bell-stone" which is unlike any rocks nearer than Cumberland or Scotland. It looks as if it were a bit of Cumberland dropped on Shrewsbury. A Mr. Cotton told Charles Darwin, when the latter was a youth, that the world would come to an end before the mystery of the "Bell-stone" was revealed.[1] Science now realises that boulders can be dropped from floating ice. Alternatively, on Tinker Bell lines, they could be dropped by giants, and this, as legend testifies, was the first alternative accepted. Now this mythological interpretation was, in part, forced upon the primitive mind by its restriction to one alternative. The stones looked as if they had been dropped or carried, and such dropping or carrying not only looked as if powerful beings had dropped or carried them, but the "as if" could not be connected with any other alternative. The original mythological conviction that giants had carried and dropped many huge boulders, because the stones were placed AS IF they had been so carried and dropped, is characteristic of a very close restriction of the primitive mind to one general alternative for explanation. Human actions do strike decisively into human lives, and these human actions are so constantly and impressively part of experience that it was no doubt natural, perhaps inevitable, for the first human thinkers to interpret all things AS IF personal beings had acted or thought in certain ways—to discover explanations in stories.

In the beginning of things, say the Kassena, the sky was close to the ground. An old woman, who was cooking her dinner, became angry because she had to stoop as if she were in a low-roofed room. In her anger she tore a piece from the sky and made in into soup. The angered sky went upwards to its present place and has remained there ever since.[2] This legend is more naïve than the Babylonian legend in which Marduk constructs the sky out of the body of the dismembered Tiamat, but is typical of the primitive preference for explanation through story. A catalogue of primitive explanatory myths which explain by personal actions would "stretch out until the crack of doom."

The progress from mythological explanation to explanation which can be called, quite intelligibly though vaguely, "scientific" is marked by the emergence of three features which are selected from many others. The first is the substitution of prolonged processes for single decisive moments; the second is the recognition of causes which are not personal; and the third is the recognition of the AS IF which connects interpretation and interpreted. In a wide survey of the course of thought, which neglects nicety of detail, these three features force themselves into notice and mark conspicuous changes in thinking. The third feature is to receive chief treatment here, but the first and second, since they are connected with it, will receive some notice.

The insult offered to the sky by the old woman was a decisive moment for the earth which settled its separation from the sky. This compression of causation into single, rapid incidents is a natural accompaniment of the story-telling method of interpretation. Single human actions have often decisive consequences and important consequences—a whole family might be put to death at the nod of a chief, or a tribe be decimated because one of its members slew a member of another. An extension of these decisive,

[1] *Charles Darwin*, ed. Francis Darwin, p. 14.

[2] Cardinall, *The Natives of the Northern Territories of the Gold Coast*, p. 23.

widespread effects of single incidents provided the primitive mind with its personal explanations of all phenomena. The "three unities" which have been alternately extolled and derided, whether Aristotle intended to enforce them or not, emphasise the dramatic effect which localisation of action in narrow spaces and short times secures. We can still realise the æsthetic quality of the dramatic compression, so congenial to the primitive mind, of big consequences into single decisive events. We can realise it in the sudden end to the Golden Age, made by the lid of Pandora's box. The Pandora myth, like all the great mythological themes, has varied in the telling. The seductive destructiveness of woman figures in all its blend of ideas. Each Olympian, when Hephæstus had made Pandora of earth, gave her a gift—Aphrodite, for example, gave her beauty, and Hermes boldness and cunning. In the original legend the fortunes of men depended upon a single act of acceptance. The beautiful thunderbolt could not be thrown, and so was led by Hermes to Epimetheus. Now Prometheus had warned him to accept no gift from Zeus. When Pandora stood before Epimetheus the fortunes of men stood in the balance; when she was taken to his arms all the miseries descended on the human race.

The extension of single decisive events into long complex processes distinguishes scientific from mythological explanation and is accompanied also by an extension of the rôle of impersonal causes. Carveth Read remarks that the anthropoids live by common sense, and savages by common sense troubled by magic and animism.[1] This common-sense core of primitive belief includes recognitions of simple causal connections such as the dependence of the penetrative power of a spear on its sharpness and the dependence of its effectiveness on the vigour with which it is thrown. Primitive man surrounds these rational recognitions with irrational magic and animistic notions: he sharpens his spear and throws it hard, but believes also that it kills by magic or is directed by a spirit. It required time to disengage the core of impersonal causation from its magical and animistic nimbus, and a greater time to extend the notion of impersonal causation to inanimate nature. Modern science has pared down the possibilities of personal efforts and extended the sphere of impersonal causes. Now the displacements of decisive moments by prolonged processes and of personal agents by impersonal forces, which are two aspects of the gradual substitution of science for mythology, had one significant lesson for human thought: they enforced the recognition of the interpretive element in all thinking.

According to a Hottentot legend death entered the world because a stupid hare mistook a message or wilfully perverted it. He was sent by the moon to tell men that though they would die like the moon dies, they would rise again as she rises. The hare blundered, wittingly or unwittingly, and announced to men that they would die permanently. The angry moon threw a stick at the hare and gave him his cleft lip. In one addition to the story the hare, in return, scratched the moon's face.[2] Since the moon's face has marks, and scratches would produce them, the situation is AS IF the legend were true. Since the AS IF fits primitive estimates of possibility more closely than it fits ours, the story was believed because it successfully interpreted facts. The human mind naturally includes interpretations that can be successfully connected by an AS IF with facts in its belief in those facts. The AS IF is ignored, or unnoticed, and the whole story, because it hangs together, is uncritically believed. In the mythological age of the human mind there was no clear recognition of the element of theory or hypothesis which pervades all interpretation. Fact and hypothesis, once successfully combined into a consistent and, to the primitive mind, intelligible tale, received equal

[1] *The Origin of Man and of His Superstitions*, p. 67.
[2] Sir James Frazer, *Folk-lore in the Old Testament*, vol. i, p. 2.

and impartial belief. The growth of the critical faculty, the division within belief into fact and interpretation, proceeded with the increasing sense of inadequacy as story-telling gradually failed to satisfy mental demands. It is probable that the dispossessed myth assisted greatly in the recognition of the AS IF which pervades human thinking, and in the estimation of its significance. The AS IF element in all thought connects into one continuity the minds of present and past ages. The realisation of the AS IF and, finally, of its implications and importance, is connected with a separation, during development, which may be compared with biological separation into species.

Lord Haldane remarks of Aristotle that " it was the fashion of his age to resort to myths and to speak in what were in those days the popular modes of expression." [1] Plato employed the myth with a full sense of the AS IF which it contained. In the dialogue known by his name Protagoras explained to Socrates why the Athenians, like all mankind, allowed only a favoured few to share in deliberations on carpentering or other mechanical arts and allowed every man to deliberate about political virtue, which proceeds by way of justice or wisdom. Epimetheus had equipped the mortal creatures fashioned by the gods with their faculties. When Prometheus inspected the distribution, he saw that men were poorly provided, so, for their salvation, he stole the mechanical arts of Hephæstus and Athene, and fire with them. Now the arts were distributed irregularly among men : a favoured few having, for example, the medicinal art, and so also with the rest. When men gathered themselves into cities to preserve themselves against the beasts, they began to destroy one another because they had no political wisdom and could not live together in justice and friendship. Hermes, commissioned by Zeus, then imparted a share of political virtue to all men that they might be able to live together.

Protagoras told his auditors, before his discourse, that he chose to speak in myth instead of arguing the question. The specialisation in human arts and common participation in the fundamental virtues which permit political life occurred AS IF the former had been first distributed and the latter then bestowed upon all. A myth which would formerly have been credible is used to describe certain facts by showing that they happened AS IF certain mythical incidents were true.[2]

When the credible myth became an incredible story, the prevalence of hypothesis in thought became clear. The Greeks perceived that interpretation was connecting observed facts by an AS IF with the supposed occurrence of other facts or events. Descartes said of Aristotle, referring to a passage in the seventh chapter of the first book of his *Meteorologics*, " with regard to things not manifest to the senses, he considers that he supplies sufficient explanations and demonstrations of them, if he merely shows that THEY MAY BE SUCH as he explains them to be." Descartes adds, on his own behalf, " I believe that I have done all that is required of me if the causes I have assigned are such that they CORRESPOND to all the phenomena manifested by nature . . . and it will be sufficient for the usages of life to know such causes." [3] Interpretation is thus definitely assigned the relatively humble rôle of connecting known events by an AS IF with the suppositious occurrence of others. Interpretation is recognised as hypothetical, and certainty perishes with the primitive myth which originally bestowed it.

As the human mind was reluctantly weaned from mythological explanations, so it has only slowly admitted the hypothetical element in its interpretations. In interpretation, A and B, which are known, are shown to happen AS IF C and D were true: chemical combination to happen, for

[1] *The Reign of Relativity*, p. 250.
[2] Protagoras.
[3] *The Philosophical Works of Descartes*. Trans. Haldane and Ross, p. 300.

example, as if it were true that elements are composed of atoms having certain characters. The dispersal of the myth which had provided the primitive mind with an interpretive context, with its C and D, showed that the mere AS IF link did not confer truth on that interpretive context. Myths were not true, though it had been possible to express phenomena as if they were. When other interpretive contexts, corpuscular theories for example, were substituted for the mythological, the ingrained dogmatic habit constantly tended to rest belief on them: belief tended to exchange for a mythological context another context because the AS IF connection commended its truth. The critical habit, prominent in Greeek thought, which realised that C and D need not be true because A and B happen as if they were, had a long struggle to impose itself. It has secured its position in modern thought, though, like the priest of the Arician Artemis, it is constantly liable to challenge. Descartes, as previously noted, appreciated the significance of the AS IF. Reid dealt with it harshly: " Conjectures and theories are the creatures of men, and will always be very unlike the creatures of God." [1] Prof. Drake, writing to-day, suggests that " everything is AS IF realism were true ": he thinks realism is true but he concedes the AS IF.[2] Prof. Rivers allows consistency as a working hypothesis to Freud's psychology of the unconscious: things do happen AS IF desires were repressed into the unconscious and appeared as abnormal mental manifestations.[3] Karl Pearson insists that science is a conceptual description, and not a plan in phenomena themselves[4]: things happen AS IF the conceptual description were, more or less, true and no other inference is warranted. " Nowadays," writes Dr. Houston, " we do not so much speak of the truth of a theory as of its utility, or rather the truth of a theory lies in its utility. . . . A theory works if it connects the facts together and enables us to predict new facts. . . . Physical theories are metaphors. When we say that light is propagated in wave motion, we mean that it is propagated like wave motion." [5]

The emergence of critical intelligence from primitive dogmatism is the emergence of a new mental species which may be compared to the emergence of mammals from lower types of life. Socrates, says Townsend, is the forerunner of all critical minds, and his Greek confrères threw their thoughts into the form of hypothetical judgments.[6] Primitive thinkers perceived that events happened as if certain stories were true, and believed impartially in both. Dr. Houston perceives that light behaves as if it were propagated in waves, and condemns belief to halt at the AS IF. AS IF is a small phrase, but the discovery of its significance is one aspect of the evolution of new mental species which is associated with the development of the critical spirit in the passage of thought from myth to science.

## THE IMPORTANCE OF PRECOCITY IN EVOLUTION.

**(A. D. Wilde)**

IN an Article published in September 1920 I propounded a theory respecting the process of Organic Evolution, which I believe to be both true and important, and to have at least some degree of novelty. Here I propose to restate that theory as shortly as possible, both on account of those who did not read, or have forgotten, that Article, and because I believe its interest

[1] *Inquiry*, vol. i, p. 1.
[2] *Essays in Critical Realism*, p. 6.
[3] *Instinct and the Unconscious*, p. 169.
[4] *The Grammar of Science*, ch. vii.
[5] *Nature*, Sept. 1, 1921, " The Present Position of the Wave Theory of Light."
[6] *Phil. Rev.*, vol. xxx, p. 4, " Education as Criticism."

and value to warrant a second exposition, especially if made, as I shall as far as possible make it, in different and more familiar language.

The theory is a corollary of Darwinism, and is so simple that it may almost be stated in a single word—precocity. It hinges on the assertion that the precocious in all kinds of life, and especially in the highest kinds, have had throughout the ages, and have now more than ever, a great advantage over their brethren less favoured in that respect. Mainly they have been the fit of each generation, and consequently the progenitors of the next, and of all creatures that have inherited and now inhabit the earth.

Let us see what can be made of this apparently insufficient material. Everybody knows what precocity is. When a child shows knowledge, intelligence, activity, and self-assertion beyond its years, it is said to be precocious. And though owing to this last quality the word is generally used in an unfavourable sense, it is evident that precocity in itself is so far from being a fault, that the early exhibition of every right activity is a virtue and a great advantage. If efficiency is right and profitable, then the sooner we are efficient the better for ourselves, our parents, and others, or there is no value in time. I therefore use the word in a favourable sense, signifying the arrival by offspring at a certain degree of efficiency in the struggle for life in slightly less time than that in which the same degree was attained by their parents. And it may be well to add at once the obvious fact that this precocious efficiency necessarily involves the equally early attainment of the structures—the "character" or sum-total of characters—to which it is due, structure and function going as always hand in hand.

As to the cause of such earlier attainment there can be no doubt. It must be a slightly greater rapidity of growth in the child than in the parent. It is the gist of the theory that such increased rapidity of growth has been a normal possession of the fit of every generation, at least of the higher animals, for ages past, and that in an increasing degree, corresponding with the height of evolution attained, the resulting precocity has been of importance in the organic world. That this general prevalence of precocity needs proof I admit, but for economy of space I shall here pass it over with the remark that the citable facts, if not exactly plentiful, are quite sufficient, and that, outside the book of nature, they are largely to be found in that great granary of information about the organic world, the works of Darwin. The occasional occurrence of precocity has for many centuries been matter of common knowledge, which has descended to us, with the word, from ancient Rome. But Darwin appears to have been the first to observe and assert its generality, which so much impressed him that in his work on *Animals and Plants under Domestication* he came near erecting it into a universal law of inheritance. To that work the reader is referred.

To return to the theory, if I am asked in what mainly has consisted the fitness of the fit in all times and of all kinds, I reply that the first and almost indispensable condition of their superiority has been rapid growth. The causes of this are easily seen. One main advantage of precocity, perhaps the greatest of all, but one which I can here only mention without elaborating, is the earlier escape so made from the perils of the environment. It is a well-known fact, and was familiar to Shakespeare, that the period of growth is in all creatures, animal and vegetable alike, a period of high, and often even of immense mortality. "In the morn and liquid dew of youth," says Laertes in *Hamlet*, "contagious blastments are most imminent." And Darwin much enlarges on the enormous destruction of the immature of all kinds. It hardly needs adding that the abbreviation of this period of danger must be correspondingly advantageous, and have great survival value.

But the cause which I now wish to emphasise is this: that the precocious of any generation, by growing a little faster than their parents, arrive at the parental level of efficiency in meeting the incident forces of the environment a little before their innate powers of growth are exhausted, and are therefore able to proceed to a yet higher level of efficiency with an accompanying additional development of structure. And the result of this addition is to make them in their turn the fittest of their generation, and the progenitors of the next. Let us note in passing that the nature of this addition is largely determined by the pressure of the environment on the still plastic organism —it is pre-eminently an adaptation, or what is called an acquired character. In addition by precocity the organism is enabled to put to an earlier test, and so profit by, any superiority which it may owe to a favourable spontaneous variation of the germ from which it grew. It is to such variations that we must still look for improvement in such developments as hair, feathers, and teeth, so far at all events as they are incapable of stimulation by exercise or the incidence of surrounding forces. But how much as a rule must an adaptation made in actual response to those forces exceed in value any improvement that can be expected to appear spontaneously!

These are the chief advantages of precocity, and they seem great enough to warrant the assertion that in a great majority of cases only those who attained the parental level of efficiency while still relatively young and adaptable—only the precocious—would have any chance of reaching the final and crowning adaptation of their own generation, and consequently a yet higher level of efficiency in the struggle for life.

Now let us suppose that in any of the higher animals the fittest of generation $B$, having by this road of precocity passed their parents, generation $A$, in efficiency, are then in their turn surpassed by the fittest of their offspring, generation $C$, then the crowning structural modification of $B$, which made its possessors the best of their generation, has become in $C$ the penultimate phase of growth, and the crowning adaptation of $A$ the ante-penultimate phase. These two phases are still attained late in the course of development, but no longer at its very end. It is still the environment that evokes and moulds them, but the response is quicker, and *they are evoked in a shorter time*. But now, if we suppose this process of acceleration to be repeated indefinitely generation after generation, what must be the result in generation $N$, taking that letter as in Algebra, to signify a number indefinitely large? Clearly the crowning adaptation of the fit of generation $A$, by which they established their claim to fitness and to be the progenitors of the future race—an adaptation reached by them only after long and arduous exercise in a hostile environment, probably among a host of rivals, and possibly by strenuous exertion of a more or less conscious will-power—would be attained by generation $N$, after the lapse of perhaps hundreds of thousands of years, in a very short time in the normal course of what is called natural growth, without exercise or the exertion of any will-power at all, and as nearly as can be without reference to the forces of the environment, as the bird is now fledged, and develops its powerful wing-muscles before ever it leaves the nest. And this, it seems to me, is what has happened in fact. In other words, by the accumulation of small, often perhaps imperceptible, advances made by individual generations, coupled with constant precocity, what we call acquired characters, and Spencer more accurately called "functionally produced modifications," have been gradually converted in process of time into congenital characters, the common birthright of every member of generations long subsequent to their origination, reached by them early in life, perhaps even (it is a question only of time for the accumulation of sufficient precocity) long before hatching or birth.

For reasons obvious enough, and good as far as they go, it is customary to draw a sharp line of distinction between the two kinds of character, germinal and acquired, and this may make it difficult to realise that they are not essentially different. But such is the fact. Acquired characters are evoked out of the growth of the germ by converse with the environment, and no character can ever be so evoked, which the germ does not potentially possess. Nor, on the other hand, can any innate or inherent character grow out of a germ, which is not evoked from it by the forces of the environment, though in the prenatal stages of growth these are heat and nutrition only. Both kinds of character therefore have a common origin in the interplay between the forces resident in the germ and the incident forces of the environment, and the difference is in the proportions in which these two elements are combined, a proportion which time continually modifies. The later the development occurs in the "ontogeny," or individual growth, the greater is the share of the environment in the result. But as fast as it travels back in the ontogeny by repeated precocity, it grows more and more by the force of nature—that is, by the inherent powers of the germ—and the influence of the environment is proportionally reduced. As to this backward travelling more hereafter ; at present I must pursue the asserted conversion of acquired into congenital characters.

If anyone finds this difficult to accept, I would still ask him whether it may not possibly be what has actually happened, in which case he must of course endeavour to rearrange his ideas more in harmony with the facts. So far as I see, there is no such difference between the processes of growth of the two sets of characters, as to make the conversion of the one into the other by slow degrees unthinkable. If we look at the individual, all his characters really originate in the germ, and the environment does but evoke their growth and normally modify only the later ones. On the other hand, if we look at the course of evolution as a whole, it may fairly be said that all characters have originated in the environment, and by continual acceleration of growth and consequent precocity all but the more recent of them have gradually become the properties of normal development, to be duly manifested in every case where nothing happens to prevent them. That such a conversion is thinkable and possible, I am confident ; *but that it is what in fact has happened, seems to me to be an opinion from which there is no escape.*

It is important to notice that this conversion of characters would be effected without any change of the germ except such as may be involved in the postulated acceleration of its growth. Some change must no doubt occur to ensure this result, but otherwise the succession of germs in a line of descent might remain unchanged from one generation to another. Not that I assert for a moment that it does so. On the contrary, for the simple reason that no two things ever were or can be exactly alike, every germ differs from every other germ in every conceivable particular of its structure, though it may be in an infinitesimal degree. And as some of the almost infinitely numerous differences thus originated in the final developments of the resulting organisms cannot fail to be more, and others less, favourable to their possessors in the struggle for life, the former will inevitably tend to perpetuation, and the latter to elimination, as Darwin and Wallace were the first to show. But the point is, that the modifications impressed on the body by its converse with the environment *are not transmitted from the structures immediately involved to the germ-cells, so as to cause similar modifications in the offspring subsequently arising from them,* whether by means of Gemmules, such as were postulated by Darwin's theory of Pangenesis, or in any other way. No such apparatus is needed to bring about a mere acceleration of growth in each generation, and I am fully convinced that Weismann was right in contending for the essential independence of the germ-cells from the "soma," or body, though of course each of these may, or rather must be and is, variously affected by the presence of the other. And on the other hand Spencer was abundantly right in contending for the cumulative effect of environmental pressure upon an evolving race. But neither of them perceived that it is by constantly repeated precocity that the accumulation takes place. The process of Evolution depends on the fact that similar forces (of the environment), acting on similar structures and forces (of the germs that grow into parent and offspring), produce similar results (in the fully developed animals, parent and offspring alike); while their dissimilarities are caused by the spontaneous variation of the germ, by the inequalities of the environment, and by constantly repeated precocity, which brings the offspring to the point reached by the parent while it has yet power to respond by further modification to the incident forces of the environment.

Whatever therefore may be the actual changes occurring in the germ, none is required by my theory except such as will cause a repeated acceleration of its development. I need hardly point out how well this agrees with recent discoveries of the function of more than one of the ductless glands to elaborate and discharge into the blood certain "Hormones," or chemical stimulants of growth.

Now from contemplation of the series of individuals in a line of descent, let us turn to the characters, or groups of characters, to which their efficiency may be due. What shall we see in these? Evidently, if they are reached by each generation in turn at a slightly earlier period of growth, all the successive phases of the ontogeny must be as it were in a state of constant movement from the end towards the beginning of the series. It is this steady backward march of *all* characters of all creatures, but especially of the higher, on which I wish to focus attention, and to which in the above-mentioned Article I gave the name of Precession, owing to the clear though distant analogy which it bears to the Precession of the Equinoxes in the solar system. The choice of a name no doubt matters not much, but I think it highly desirable that this hitherto unnamed universal movement should have one, as being a phenomenon of the highest importance in the organic world.

Besides precocity, it will readily be seen that it is this movement which has brought about what is called "Recapitulation" in embryonic growth—the well-known fact that every animal in its early growth passes through phases that indicate in some degree, be it great or small, the remoter ancestry from which its species has sprung. The Ontogeny, in technical language, recapitulates in a few months at the longest, the Phylogeny, or secular evolution of the race. The backward movement of all characters, coupled with the constant reduction of their growth-time, leads eventually to the more ancient of them being crowded together into the earlier periods of growth, and recapitulated instead of undergoing the almost exact repetition shown in offspring of all the successive developments of the parents. What were once the final and crucial attainments of growth, and determined the preferential survival of their possessors as the select out of the common herd, pass back by Precession until they become inherent growth-properties of the germ, the common birth-right of every member of the species; and then, having survived their usefulness, still pass back so as to become temporary and unimportant phases of embryonic growth, like the external tail in man, still conspicuous in his embryo; and then are yet further reduced, until, like the hind leg-bones in Sperm-whales, of which it is said no rudiment now appears even in embryonic growth, they finally pass out of existence altogether.

By way of exemplification let us consider a little the question of the teeth, which owing to their hardness have survived in such numbers in a fossil state as memorials of the fauna of ancient times. From these it is clear that in many cases a dentition that was a useful and important character of the maturity of an ancient creature now known only by its fossilised remains, appears in its modern descendants merely as an evanescent development of immaturity, rapidly formed perhaps long before birth, only to be as quickly reabsorbed. Or possibly it never even appears at all. Thus at one time all birds were toothed, including the ancestors of all modern species, while now all are practically toothless, but in the embryos of some it is credibly asserted that rudiments of teeth "can be detected." The true Whale, which when grown up has not a tooth in his head, the "Whale-bone" having replaced an ancestral dentition, has manifest teeth while in the fœtal condition. And teeth which never cut the gums are present in the upper jaws of our domestic calves before they are born. How can these facts be interpreted except in the light of the theory of Precession, according to which the teeth in all these cases, except where they are already extinct, are on the way to complete extinction by constantly repeated precocity in their loss? Among the more civilised races of men the human teeth, to the alarm of many who regard it as a sign of decadence, are now often lost early in life —earlier, it is said, with us than in our fathers' and grandfathers' times. May this not possibly be because the practice of softening the food by cookery, most prevalent among the most civilised, whose offspring in all probability will mainly inherit the earth, makes so powerful a dentition ever less and less useful? And may not our teeth have embarked on that journey to annihilation, which has long since been complete among the birds?

For the exposition of further examples I have no space, but I would add that none could be more instructive than the attempt to imagine the process by which our modern birds and their wonderful powers of flight have been developed from a reptile that could not fly at all. Whoever undertakes this with an open mind will, I think, hesitate to assign limits to the share that constantly repeated precocity has had in the result. The astonishing rapidity of the metamorphoses of insects; the facts of hybridism as shown in the ordinary mule; and the origin of certain species differing little in structure but much in habits, and on that account called Habitudinal, are minor questions of Biology on which the theory of Precession will throw a main of light.

If, however, all characters alike tend by Precession to reduction and final disappearance, how is it that any, even of the most useful, remain? It is because useful characters, such as the brain and the hand in man, the increased efficiency of which now largely determines his selection and survival, *are still constantly undergoing changes and additions of structure, which involve additional time spent in growth and a longer life; while the useless and indifferent organs, one form of which is as good as another, gain no additions either in structure or in time, and are thus left gradually behind.* Hence the short life of the tail in man, which is still conspicuous at a very early period of his growth, but soon completely absorbed except a few still useful bones. This is the way in which useless members and organs are discarded from the organism. They go, not because of any considerable advantage gained by those who have them in smaller size, but because every member and organ which is to keep its place, and not be left behind by the rest, must undergo additional variation, involving the consumption of additional time in its growth.

To attain a clear view of the subject, we must consider it not statically as usual, but as far as possible kinetically, as a matter of processes and movements. Selecting the best terms to be found for its expression in this light (poor as they are) we must describe the life of any animal, in growth and decay, as a series of developments, positive and negative, the former predominating at the beginning and the latter at the end of the series. Any succession of animals in a line of descent (there ought to be a name for this, the homologue in time of a species in space) is a succession of such series of developments, generally similar, but differing in particular by the constant addition of new developments at the end of each series, and the constant suppression of old ones at the beginning. There is thus a clear contrast between the methods of growth of Ontogeny and Phylogeny, but the accretions of the latter are mainly made, not at the end of life, but at maturity, the end of growth.

It has often been asked, if acquired characters are inherited, or rather accumulated (as I assert they are by Precession, though not through the germ), how is it that artificial mutilations, like the docking of dogs' tails, inflicted for centuries on every generation, show no tendency to be inherited at all? If the natural loss of characters takes place, as I contend, by Precession, the reply is evident. A mutilation inflicted on every generation in turn *at the same age* cannot be expected to show any tendency to reappear in posterity at an earlier one. Here then is confirmation of the theory in the shape of an old difficulty simply explained.

There will, I hope, be no difficulty in imagining this secular movement of Precession which I believe to be manifested increasingly throughout the ages of organic evolution, but in the hope of making it yet clearer I will avail myself of the best illustration I can think of among familiar movements. Suppose a telescope to be slowly but continuously shut up, but at the same time to have fresh joints of equal length added at frequent and regular intervals of time to the object end. And suppose the shutting to affect all joints equally, and to be at such a rate as not quite to neutralise the effect of the additions. Then clearly the telescope grows very slowly in length, and every joint, because of the additions made at one end only, travels steadily backwards, always shortening as it goes, towards the eye-piece, on reaching which it finally closes up to nothing. The telescope typifies the lives of a series of animals in a single line of descent, and its new joints are each the new characters or additional modifications of a single generation, while its eye-piece is the germ. As it slowly gains in length, so do the most highly developed animals take the longest time in growth and have the longest lives. The movement of the fresh joints towards the eye-piece, always shortening as they go, and their final successive elimination, illustrate the movement of Precession of characters, by which, originally attained at maturity and directed and moulded by the forces of the environment, they end in being attained in the earliest phases of growth, and then passing out of existence altogether. It may be well to add, however, that while the movement of such a telescope would be a real movement of the parts of a single object, that which it typifies is an appearance only, arising, like that of a cinema picture, from the successive presentation to the mind of a series of objects similarly differing from each other.

It will be seen that I look on the effects of the environment upon a series of animals in a line of descent as being, figuratively speaking, gradually thrust back into the germ by constantly repeated precocity caused by accelerated growth, and the addition by each generation of an adaptation somewhat in advance of its predecessors. And I think the establishment of the movement of Precession will be sure to lead to a revision of opinion as to the rate at which evolution may have proceeded and be proceeding now, especially in the case of those who suppose that all depends on the spontaneous variation of the germ.

Such then, as well as I can sketch it in bare outline, is the theory of the process of evolution which I published in September 1920, and I am in no doubt it will eventually be found to show that consonance and concatenation with old-established truths which, with apologies to Spencer, is the only test of the validity of new ones, and to lead to a better understanding of many phenomena of evolution than has hitherto been reached. Indeed, the movement I call Precession harmonises and unifies a great number of ascertained facts: those of recapitulation in the early stages of life, those of precocity in the attainment of a full development, those of comparative longevity, and those of the riddance from the species of limbs and organs that have become useless to the individual. Finally it solves the much-vexed problem of the inheritance of acquired characters. Had it been published in the last century at the time when the controversy on that problem ran so high, mainly between Spencer and Weismann, it would perhaps have attracted some notice and been made the subject of discussion; but much has happened since then to draw public attention away from such matters, and the present century apparently cares for them but little. Yet the problem whether the effects of the environment upon the organism are accumulated in successive generations, and how, is as important as ever before.

In some quarters I have been told that there is nothing new in the ideas here set forth, but to that statement I demur. For had it ever been realised that every acquired character, or in Spencer's more accurate language, every functionally produced modification, once fairly established, inevitably tends to travel backwards in the ontogeny, becoming in each generation less and less an adaptation to the forces of the environment, and more and more a "natural" character, until it is acquired early in life as the common birthright of the whole species—the moment this was realised, the controversy on the inheritance of acquired characters must forthwith have dropped. For it follows that an acquired character, be it ever so adaptive in origin, once it has travelled far enough back in the ontogeny to be acquired without any exercise or effort at all, is inherited just as much or as little as, and in fact has become, an innate or congenital character. But so far as I know, though controversy on the subject is dormant, the question is considered an open one to this day. So recently as the 14th of March last the Scientific Correspondent of *The Times*, in an Article headed, "Are Variations Directed?" put the problem in this way: "Certainly there has been a great increase of knowledge as to the part played by the environment in moulding each individual life, but as yet neither observation nor experiment has afforded any but the faintest suggestions *that these effects on the individual can be transmitted to progeny in such fashion that they will reappear with a smaller contribution from the environment*" (my italics). This then is the still open problem, and the solution, if I am not mistaken, is contained in what I have written above: namely, that though the impress of the environment is not transmitted from parent to offspring, yet it does reappear in them "with a smaller contribution from the environment," *because it is developed by each generation in succession in a shorter time.* Hence arises, wherever the environment, as is usual, is relatively stable, that continuity of variations upon the same line through many generations, which for example has been so conspicuous in the evolution of the horse.

These views may, I fear, not be everywhere welcome at present. The official scientific creed of the day is of course Mutation, and has been so for many years. In a paper such as this it would be absurd to attempt the refutation of a theory so widely held, but it is easy to set down a few of the more obvious respects in which Precession seems to fit in far better with the scheme of Nature.

In the first place, it is not, be it said, that there are no mutations—the Nectarine is a fact. Nor need I argue that no new species ever arose by mutation of an old one—the Nectarine, for all I know, may be entitled to specific rank. But it is that this has not been the way of Nature in the evolution of the higher animals, or in particular of man.

To touch on the wider aspect of the matter, it seems to me that ever since the brain of man, already for long ages his chief weapon in the struggle for life, first began among the ancient Greeks to open to the light of abstract reason, three closely connected truths (among others) have ever been impressing themselves deeper and deeper on his mind:

First, the instability of things—the fact that the whole universe is in constant motion and consequently undergoing constant change; the doctrine so pithily expressed by Heracleitus in the two words "Panta rhei."

Secondly, the vast importance of the little, both in matter and in force. Not only on the material side is the truth that many a little makes a muckle ever receiving fresh illustration; but on the immaterial, that small causes, acting cumulatively over long periods of time, produce effects of immeasurable greatness, is a doctrine that received striking extensions of application in the last century, especially at the hands of Darwin and Lyell.

Thirdly, an obvious corollary of the other two, the uninterrupted process of things in a smooth unbroken course, sliding from one state of things into the next, and making neither stop nor jump. "Natura non facit saltum" is a saying not only old, but also true.

With these principles Darwinism is thoroughly in harmony. It was an advance of the mind of man upon already familiar lines. Putting it roughly and roundly, Darwin and Wallace asserted that time may change an amœba into a monkey and a monkey into a man by the age-long accumulation of small differences, such as may to-day be seen between two plants or two animals of the same species, whether wild or in domestication.

An equal consonance with these old-established truths may be claimed for Precession. Take the small amount of Precocity that may any day be seen occurring in a single generation, multiply it by the number of generations supposed to have intervened between now and (say) the Eocene, and the resulting changes might perhaps be as marvellous as those which have happened. Not only so, but Precession is even a necessary supplement to Darwinism, showing as it does how that constant accumulation of small increases of size or development or both, which Darwin postulated as occurring through thousands of generations, *every one of them involving a small increase in the time consumed in the growth of the individual*, is made possible without an inordinate increase in the total length of the growth-time, and the postponement to a hazardous future of the attainment of maturity. Were it not for the slow but unceasing compression in point of time of all its developments except the last, and of that last as soon as in the next generation it has become penultimate, no animal of the higher orders of now-existing life could have ever come into being at all. All their progenitors must have perished on the long journey to maturity.

Mutation, on the other hand, is the child of a reaction against Darwinism, and in direct opposition to the three ancient principles I have cited, denies the sufficiency of an accumulation of small changes to produce such vast results. It thus traverses the belief that Nature is in a state of constant change and flux, for the sudden jumps by which species are supposed to have arisen must have alternated with periods of rest, or what has become of the effects of the series of small changes which intervened? Moreover, Mutation to my thinking is an explanation which does not explain; it is nothing but special creation by more or less numerous instalments.

In the kindred science of Geology there is an instructive parallel and precedent for such a departure as this from the long accumulation of human experience gathered and enshrined in the three doctrines cited. At the beginning of the nineteenth century there were two competing views as to the origin of those surface-rocks that come within our purview, called by Whewell the Catastrophic and the Uniformitarian. The following account of the former is taken from Prof. J. W. Judd's *Cambridge Manual*, "The Coming of Evolution": "That at a number of successive epochs—of which the age of Noah was the latest—great revolutions had taken place on the earth's surface; that during each of these cataclysms all living things were destroyed; and that, after an interval, the world was restocked with fresh assemblages of plants and animals to be destroyed in turn and embedded in the strata at the next revolution." In other words, that the course of Nature in the building of the world in times long past had been discontinuous, by jumps or Geological Mutations. Our present Mutationists are the Catastrophists of Biology; "discontinuity" is ever on their lips. Lamarck, Darwin, and Wallace, were its first Uniformitarians. Largely through the influence of Lyell, it was Uniformitarianism that won the day in Geology, and Catastrophism is now extinct. Possibly the day is at hand when a similar fate will overtake Biological Mutation, and I venture to predict to the reader that when that happens, its successor will be the Theory of Precession now under its eyes.

## MODERN ASPECTS OF WATER PURIFICATION (R. J. S. McDowall, M.B., D.Sc.).

THE problem of water supply has been of vital importance and interest to the people of all time, and even to-day is one to which some of the most modern discoveries are applied.

The ancients simply sought an ample source of supply and conveyed it to the desired place by aqueducts, often of great length. Fortunately, too, they possessed a natural immunity to many of the diseases prevalent now in more civilised communities. Gradually, however, the ever-increasing population necessitated larger supplies, and the higher races lost their immunity, with the result that the provision of a water supply good both in quality and quantity became a most important question wherever people congregated together. Thus the utilisation of sources of doubtful purity became necessary as did also the introduction of water purification systems.

During recent years, the outlook on such questions has been considerably modified as the result of the great success which has attended the purification of water by chlorine, especially during the war, and there seems every reason to believe that the chlorination method will in course of time largely replace the methods at present in use.

Hitherto the *pièce de résistance* in water purification has been sedimentation and slow sand filtration, together or separately according to requirements. Simple storage or sedimentation has been found to cause the destruction of some percentage of the organisms and, if the water is reasonably good at first, this may be considered sufficient; but usually the water is passed from the storage reservoirs to slow sand filters. The essential part of the latter is fine sand supported on coarser sand and rubble, but the most of the purification takes place at the surface of the sand, where a scum forms which is the most efficient part of the filtering medium. Unfortunately, as the scum becomes thicker, the flow through the filter becomes less until it is insufficient for requirements, and, although the filter may be working excellently from the bacteriological point of view, the scum has to be removed. This is often a very laborious and expensive process. The cost of running such a plant and the initial cost of installation, which may include the purchase of land, is very great, and it is but natural that any other methods which reduce the expense without sacrifice of efficiency should receive a due consideration. Until the war, however, little attention was paid to the question, at least in this country, most authorities being satisfied at having arrived at a reliable method of purification. But, as we shall see, the war has changed the outlook, and now the chlorination introduced by the late Sir G. Sims Woodhead looks like supplanting the older method in spite of considerable opposition.

This method depends on the fact that free chlorine in very dilute solution, 0·5–1 per million, will kill all pathogenic organisms in water provided there is no other organic material present which will take up the chlorine. There are several ways of introducing the chlorine, but that usually adopted is that in which use is made of bleaching powder—which, if of proper strength, should contain a third of its weight of chlorine, which is liberated when the salt is dissolved. A concentrated bleaching powder solution of known strength is allowed to run into the water system at a convenient point where thorough mixing can be assured, the actual amount being determined by the bacteriological requirement of the water and the amount of water flowing in the system at the point where the solution is introduced. Once the amount to be added has been determined the process can be carried out by unskilled labour, together with periodical bacteriological examination.

The cheapness and simplicity of the method recommends it to the economist, but there are still a few in this country who would fain throw doubt on its efficiency, although war experience has undoubtedly reduced their number. One wonders sometimes how far the opposition is fostered by those who have a special interest in the costly installation and skilled supervision of the older variety of plant. Moreover, chlorination relies solely on the bacteriological examination of the purified water, *i.e.* the evidence of presence of living organisms as the standard of efficiency, and this has aroused the ire of certain chemists who have hitherto looked upon chemical evidence of past impurities as being the best standard to go by. Also the conservatists consider that in slow sand filtration we have a method which has stood the test of time, and there is no justification for replacing by a method which has not been so tested. To those who say that chlorinated water has necessarily a disagreeable taste, it can only be said that they have not experienced a properly chlorinated supply.

War did much to further the progress of science, as did science the progress of war, and in the chlorination of water we have an example of both. Two instances need only be given, namely, the Mesopotamian and Egyptian campaigns. Without a simple method of efficient purification of water it is difficult to imagine how the advance on Bagdad or the crossing of the Sinai Desert could have been carried out by such large bodies of men in the time done. Compared with these, all previous campaigns were miniatures.

The writer was associated with the latter, of which a few illustrative details will be given.

Along the first part of the route followed across the Sinai Desert from Egypt to Palestine is a chain of wells, and this was sufficient for the advance guard, as it was for the small army of Napoleon, but it was quite insufficient for the main British army. The eastern part of the Sinai Desert is practically waterless, and it was on the other side of this waterless area that the Turks had entrenched themselves and actually managed to hold up our advance for over a year. It was therefore necessary to provide the army with water from outside Sinai, and the only one possible was the fresh-water canal which takes the water of the Nile to Ismailia, Port Said, and the other stations along the Suez Canal. When it is considered that this canal leaves the Nile near Cairo and flows through some 70 miles of the Delta, where it is exposed to every conceivable pollution, and that in addition it is bilharzia-infected, it will be seen that the problem of purifying the water for consumption by troops was no light one.

In the ordinary way, such a polluted source would never be considered for a municipal supply in this country, but in Egypt there was no choice, nor was it to be expected that the army would go to the expense of the installation of a slow filtration plant, even if such a method had been feasible in the dust-swept desert areas where the purification had to be carried out. Moreover, at Kantara, which was the base of the advancing force, space had to be economised, as in many parts the brackish ground water was very near the surface.

It was realised that it was of negligible importance what the results were as regards albuminoid nitrogen if a water could be provided which was bacteriologically safe. To attain this end, rapid filtration plants were erected and arrangements made for chlorination. To give an idea of the amount of purification required, it should be stated that the colony count usually exceeded 1,000 per c.c., indeed was often uncountable by ordinary means, while bacillus coli was frequently present in 0·05 c.c.

The success of the method will be seen by the results when it is stated that throughout the campaign not a single epidemic occurred which could in any way be attributed to this water supply, although conditions for the spread of disease were most favourable. The supply from the purification plant at Kantara, for example, was originally intended to supply 500,000 gallons a day for a small force of three divisions detailed to recapture the Egyptian frontier towns of El Arish and Rafa, to which the water was pumped in stages through a 12-inch main laid upon the desert sand. It proved so successful, however, that when the conquest of Palestine was contemplated, the pipe-line continued to follow the advancing troops and was subsequently laid on to the Gaza-Beersheba line, a distance of 147 miles from the purification plant and 220 from the Nile.

A similar story could be told of the Mesopotamian campaign, in which the water supply was for the most part drawn from the Tigris, sedimented and chlorinated.

At home, too, the Metropolitan Water Board, forced by the exigencies of war which demanded economy of coal and labour, had set themselves a similar problem. In the thirteenth Research Report, Sir A. C. Houston sums up the position thus :—

" Is it permissible to filter stored water so rapidly as to create an economic gain in the saving of the filtration area, yet by the aid of anti-filtration or post-filtration sterilisation processes to produce a water which is safe, innocuous, tasteless, and reasonably satisfactory from a physical and sentimental standpoint ? " The subsequent reports on the London supply show beyond doubt that the answer is in the affirmative, and that as regards economic gain there has been a saving of thousands of pounds yearly since the adoption of the chlorination method.

The latter method is being extensively used in America, indeed bleaching powder can be so cheaply made as a by-product at the great electric stations that chlorine is also being used in the purification of sewage also.

Thus has a method of water purification, which was chiefly elaborated during the stress of war and which might otherwise have been largely neglected for many years, been brought into prominence and shown itself to be one capable of being of great benefit to civilisation in times of peace.

REFERENCE.—McDowall : " The Water Supply of the Egyptian Expeditionary Force," *Journ. Hygiene*, 1921.

# REVIEWS

## MATHEMATICS

**James Stirling : A Sketch of his Life and Works along with his Scientific Correspondence.** By CHARLES TWEEDIE, M.A., B.Sc., F.R.S.E. [Pp. x + 213.] (Oxford : at the Clarendon Press, 1922. Price 16*s.* net.)

THE life of James Stirling, of Stirling's Theorem, is full of interest. He was born in 1692, and at Balliol College, Oxford, was involved in the Jacobite disturbances of 1714–16, when "mobbs begun to pull down meeting houses and whiggs houses." In 1716 he was tried at the Assizes for "cursing K. George," but was found not guilty. It is commonly stated that he was expelled from Oxford for his Jacobite leanings, but this is not borne out by the entries in the Diary of Thomas Hearne, the antiquary, which form our chief source of information for this period of Stirling's life. Anyhow, he lost his Snell and Warner Exhibitions "upon account of the Oaths" and went to Venice with Nicholas Tron, Venetian Ambassador at the English Court, after having published, in 1717, a commentary on Newton's *Lineae Tertii Ordinis*. He was offered a chair of Mathematics, in which University is not quite clear, but had to refuse it on account of his religion. To this period belongs a letter of thanks to Newton, which has been printed before by Brewster. From 1719 to 1724 we lose sight of him, but in the latter year he was in London, where he taught Mechanics at Watt's Academy in Little Tower Street, in which he had acquired an interest. He was admitted to the Royal Society in 1726, and became acquainted with most of the mathematicians of the day—Maclaurin, Cramer, N. Bernoulli, Euler. In 1735 he was appointed to the managership of the Leadhills Mines in Scotland, and held it till his death in 1770 ; but his removal from London and his business activities, in which he was extremely successful, necessitated his giving up his mathematical work.

Mr. Tweedie gives a summary of Stirling's works, the commentary on Newton above referred to, the *Methodus Differentialis* (1730), by which he is best known, which is concerned with the Calculus of Finite Differences, and which contains his series, and his papers in the *Philosophical Transactions.* But the greater part of the book is occupied with Stirling's scientific correspondence, preserved at the family seat of Garden. There are also four letters to Maclaurin in the Maclaurin MSS. at Aberdeen. Most of the letters are to Stirling, from Maclaurin, Cramer, and others, and they throw a good deal of light upon obscure points in the history of mathematics.

Mr. Tweedie is to be congratulated upon a scholarly piece of work, which it is to be hoped will result in the discovery of further letters of Stirling.

F. P. W.

**First Course in the Theory of Equations.** By LEONARD EUGENE DICKSON, Ph.D. [Pp. vi + 168.] (New York : John Wiley & Sons, 1922. Price 8*s.* 6*d.* net.)

THIS book differs essentially from the author's *Elementary Theory of Equations,* being intended for younger students, the proofs employed being simpler and more detailed. A welcome novelty is Chapter III, Constructions with Ruler and Compasses, which explains, for instance, why regular polygons of 5 and 17 sides can be constructed, while those of 7 or 9 cannot. Chapter VI deals with the isolation of the real roots, with the theorems of Descartes, Sturm, and Budan; and Chapter VII with Horner's and Newton's methods for the solution of numerical equations; both are workmanlike and scientific. There follow chapters on determinants, symmetric functions and elimination, and, in an appendix, a proof of the fundamental theorem on the lines of Cauchy. There are numerous examples, references, and historical notes, and an adequate index.

It is to be hoped that the book will have a wide circulation. F. P. W.

**Readable School Physics.** By J. A. Cochrane, B.Sc. [Pp. xi + 131, 8 full plates and 62 illustrations.] (London: G. Bell & Sons, 1922. Price 2*s.* 4*d.* net.)

The author in his preface states that this is an attempt to humanise elementary physics without popularising it. He seems, however, to some extent to have fallen between two stools. While attempting on the one hand to give an historical and human basis to the study of science, he has not produced a textbook or course of study which could be followed by the average teacher. As a supplementary reader the book undoubtedly will be of value to the practical teacher or student, but it is difficult to judge from a reading of the book at what stage or stages in the school course the various parts of the book should be read. An instance of this difficulty of using the book to supplement or supply altogether a school course is seen in the chapter on Surveying. Many schools are now having a graded course of surveying as part of their mathematics. The author rightly includes a description of the simple anglemeter, but gives no explanation of the optical part of the instrument. He states: "A slight knowledge of the laws of light (which branch of physics you will study later) enables us to find the angle required. As a matter of fact, the angle is simply read off from the instrument." Surely this is an excellent opportunity for teaching the elementary law of physics referred to. It seems such a pity still to adhere to the old habit of giving children their scientific knowledge in separate and water-tight compartments.

W. C. B.

## CHEMISTRY

**A Dictionary of Applied Chemistry.** Vol. III. By Sir Edward Thorpe, C.B., F.R.S., assisted by Eminent Contributors. Revised and enlarged edition, with illustrations. [Pp. viii + 735.] (London: Longmans, Green & Co., 1922. Price 60*s.* net.)

This dictionary is too well known to call for a description of its scope and arrangement. In the new edition now appearing the work has undergone considerable enlargement and revision; as examples may be quoted the expansion of the article on Explosives from 72 to 98 pages, on Fermentation from 35 to 40 pages, and on Glycerine from 13 to 17 pages. The article on Coal-gas, though not markedly longer in the total number of pages, has been revised and improved by economy in the space devoted to questions now of less importance, such as the determination of illuminating power, and expansion in other directions. Although some of the shorter articles have been reprinted unchanged, there is no doubt that the present edition constitutes an improvement on the previous one and represents a great deal more than a reprint with minor corrections. It is a matter of doubt how far illustrations of plant other than purely diagrammatic ones are of use in a book of this kind, which cannot aim at giving the reader more than a general survey of any particular industry. Nevertheless, it is a pity that greater uniformity has not been adopted in the articles in this respect; that on Explosives does not contain a single diagram, while the article on Glass contains an illustration of a bottle-making machine (Fig. 8) of great complexity which is unintelligible from the description of fourteen lines given in the text. As the articles are written by recognised authorities the information is reliable, though a few errors and omissions have been noticed. For example, pure trinitrotoluene is described as being non-toxic and readily soluble in alcohol and light petroleum, while the very important series of Technical Records published by the Ministry of Munitions finds no place in the Bibliography on Explosives. The importance of the Grignard Reagent in the preparation of certain synthetic drugs justifies more space being given to it than eight lines; it is at least as useful as pure fluorine, the preparation and properties of which occupy nearly two pages. Except, however, for such small blemishes the book is of great use for rapid reference, particularly to the industrial chemist who has not ready access to a well-stocked library.

O. L. B.

**A Concise History of Chemistry.** By T. P. Hilditch, D.Sc., F.I.C. Second Edition, revised. [Pp. xi + 276, with 16 diagrams.] (London: Methuen & Co., 1922. Price 6*s*. net.)

Many advances in chemistry have been made since the publication of the first edition of this history in 1911, more particularly in connection with the elucidation of the structure of the atom; in this and other respects the work has been revised and brought up to date. The book is not arranged on a chronological principle, but deals in turn with the evolution of various fundamental ideas and the development of the different branches of the subject. The author has laboured to justify his title, with the inevitable result that in some cases compression has reduced the chapters to little more than a chronological record; this is particularly noticeable in the chapter dealing with the history of physical chemistry. The absence of biographical details, though in many ways an advantage, robs the history of chemistry of much of its human interest, but the method of treatment supplies a very readable résumé of the advance of chemical knowledge, though it presupposes a fairly intimate acquaintance with modern chemical theories.

Perhaps the best chapter is that on the ultimate constitution of matter, which in twenty pages traces very clearly and concisely the development of this subject from the days of Democritus to the theories of Langmuir and Rutherford. It is pleasing to note that due credit is given to Crookes as a pioneer in this field, but it is perhaps somewhat pedantic to adopt the spelling Mendelejew for the discoverer of the Periodic Classification. The book, apart from its limitations, is well written and can be recommended to advanced students who wish to clarify their outlook and to get a truer perspective than they are likely to obtain amidst the mass of detail which so often crowds lectures and textbooks.

O. L. B.

**Inorganic Chemistry.** By Martin Lowry, C.B.E., M.A., D.Sc., F.R.S., Professor of Physical Chemistry in the University of Cambridge. [Pp. x + 943, with 285 figures.] (London: Macmillan & Co., 1922. Price 28*s*. net.)

The nature and scope of inorganic chemistry has been profoundly modified during the last fifty years by the influence of "physical chemistry," as Prof. Lowry points out in his preface.

For this reason it is now possible to re-write many chapters of the science in the light of the newer knowledge, and full advantage has been taken of this in preparing the present work.

We may inquire perhaps whether the so-called "physical chemistry" is really a separate branch of the science or whether it is not, in fact, simply the third and last stage in the development of inorganic chemistry which completes and rounds off the work of the earlier descriptive and classificatory phases ?

At all events the author has made full use of such modern developments as equilibrium diagrams and the like, which serve to make clear many matters otherwise difficult for the student to grasp.

The initial chapters are adapted from the author's *Historical Introduction to Chemistry*, from which it will be gathered that the historical method of approach has not been neglected. A useful device for students is the inclusion at the end of each of the earlier chapters of a "Summary and Supplement" which will aid materially in revision of work.

Prof. Lowry has been fortunate in securing the collaboration of various fellow-chemists, of whom Dr. A. S. Russell (Radio-activity), Dr. F. W. Aston (Isotopes), Prof. W. Turner (Glass), and Mr. F. Renwick (Photography), may be mentioned as contributing sections dealing with their special subjects.

The only comment that might reasonably be made by an "Advocatus Diaboli" is whether too much is not attempted in writing a book which begins with the very rudiments and carries on right into the most advanced portions of the subject ? Either the beginner will be confused by the apparent complexity of his subject or, alternatively, a large portion of the book will remain unread by the senior man. This, however, is by the way.

It would be invidious to compare the book with certain other excellent textbooks of inorganic chemistry which have recently appeared, but quite certainly Prof. Lowry's work is among the best of its kind, and anyone who could claim to have read it through and absorbed its contents would certainly have a very good knowledge of inorganic chemistry.

F. A. Mason.

**Isotopes.** By F. W. Aston, D.Sc., F.R.S., Fellow of Trinity College, Cambridge. [Pp. viii + 152.] (London: Edward Arnold & Co., 1922. Price 9*s*. net.)

In collecting and publishing in book form the results of recent researches on the measurement of atomic weights by the methods of positive ray analysis, Dr. Aston has done a real service to all students of physics and chemistry.

The subject is treated in historical sequence, so that the first isotopes considered are those belonging to the radio-active elements. After an excellent summary of the work in this field the author discusses in greater detail the light which positive ray experiments have thrown on the nature of the so-called elements. He describes first Sir J. J. Thomson's parabola method, which resulted in the discovery that neon was not an element of atomic weight 20·2, but a mixture of two isotopes of atomic weights 20 and 22, but with exactly the same chemical properties. The need for an instrument of greater precision led Dr. Aston to design the mass-spectrograph with which atomic weights can be measured with an accuracy of one part in a thousand. The instrument is described in detail, and the description leaves the reader marvelling at the ingenuity and experimental skill of the author. The results so far obtained with this instrument are collected together, and are of far-reaching importance to physical and chemical theory. Comparatively few of the elements examined are simple ; by far the greater proportion are mixtures of isotopes, the number of the isotopes varying widely. Great stress is laid on the fact that, if oxygen be taken as an element of atomic weight 16·00, the other elements examined have atomic weights which are exact whole numbers or are mixtures of isotopes whose atomic weights are whole numbers. The only certain exception to this whole-number rule is hydrogen, which is shown to have an atomic weight of 1·008 in close agreement with the accepted value.

An interesting discussion is given of the meaning of these results and their bearing on modern atomic theory. Here Dr. Aston allows his imagination more freedom and has much that is interesting to say on such questions as the structure of the nucleus, the meaning of the whole-number rule, and the relation between atomic number and atomic weight. The author's remarks on the question of the evolution of the elements at present existing in the universe are sufficient to show what a far-reaching effect experiments such as these considered in this volume may yet have on very fundamental scientific questions. The discussion of the deviation of the atomic weight of hydrogen from an exact integer is of particular interest. It is shown that the apparent loss of weight and consequent emission of energy which take place when four hydrogen nuclei or protons combine to form a helium nucleus may possibly provide an explanation of the maintenance of solar energy. This section of the book, while admittedly speculative, is full of most inspiring suggestions.

The concluding chapters are devoted to the consideration of the spectra of isotopes, and their separation by other physical and chemical methods. Emphasis is laid on the extraordinary difficulty of this separation when it depends on dealing with the average effects of vast numbers of atoms, and not with the effect of individual atoms as is the case in the positive ray tube.

Dr. Aston is to be congratulated on having produced a volume which will not only be a valuable addition to the library of the specialist, be he physicist or chemist, but which will also make a strong appeal to the general reader who is interested in the present-day developments of science. This can, unfortunately, be said of too few modern books on scientific subjects. The copious illustrations, both plates and diagrams, and excellent type add considerably to the pleasure to be derived from reading this volume.

G. S.

**Organic Syntheses: An Annual Publication of Satisfactory Methods for the Preparation of Organic Chemicals.** By Roger Adams, Editor-in-Chief. Vol. I. (Pp. vii + 84, with 7 illustrations.] (New York: John Wiley & Sons; London: Chapman & Hall, Ltd., 1921. Price 8*s*. 6*d*. net.)

This book owes its origin to the fact that during the war the American chemists were cut off from foreign supplies of research chemicals. As a result the preparation of many organic chemicals was worked out in various universities on a scale large enough for use as starting material for research. The directions given in this volume are for the preparation of alkyl bromides, alcyl alcohol, benzene sulphonic chloride, benzil, benzilic acid, benzoin, α-bromonaphthalene, *p*-bromophenol, diacetone alcohol, furfural, mesityl oxide, methylene iodide, methyl hexyl carbinol, anhydrous oxalic acid, thiophenol, trimethylamine, and trimethylamine hydrochloride. The directions are clear and supplemented with diagrams of apparatus where necessary. They are followed by notes on the process, other methods of preparation are indicated, and full references to the literature up to January 1921 are given. This volume should prove very useful to the research chemist, who will look forward to other volumes in succeeding years. The methods have been worked out in one laboratory, and checked in a second, before being published. This makes the book the more valuable, as the instructions may be relied upon to give the yields stated. The yields of substances prepared vary from about 100 grams to 2,000 grams.

In the preface the authors request that other research workers will assist in the preparation of these volumes by sending particulars of preparations of any other organic chemicals, which they have made on a fairly large scale, for verification and publication.

J. N. E. D.

**Power Alcohol: its Production and Utilisation.** By G. W. Monier-Williams, O.B.E., M.C., M.A., Ph.D. [Pp. xii + 323, with illustrations.] (London: Henry Frowde and Hodder & Stoughton, 1922. Price 21s. net.)

The title of this book conveys but a very imperfect impression of the comprehensive nature of the treatment of the subject with which it deals. The book opens with a chapter on the motor fuel question, and discusses the relative merits of petrol and alcohol from the point of view of cost of production; it is pointed out in this connection that the advantage is all in favour of petrol so long as supplies keep equal to the demand, but that when this is no longer the case power alcohol will begin to be regarded in the first instance as a supplementary rather than as a competitive fuel. In the second chapter entitled, "The Plant as a Source of Alcohol," the author gives an up-to-date and lucid account of our present knowledge regarding photosynthesis and the mechanism of alcoholic fermentation. The third chapter deals with the various raw materials and the production on a large scale of alcohol from starch and sugar in the brewery and distillery, together with details of the stills employed in British and foreign practice. The fourth chapter is devoted to the economics of alcohol production from various plants, together with the average yield obtainable from the various sources mentioned. Chapter V contains a comprehensive account of the experiments which have been carried out within the last few years, more especially in Scandinavia and America, upon the production of alcohol from cellulose materials. In Chapter VI is described the production of synthetic alcohol, and Chapter VII deals with Excise Supervision and Denaturation. The ninth chapter, which is one of the longest in the book, contains data concerning the physical properties of alcohol from the motor fuel standpoint, such as calorific values, temperature of spontaneous ignition, explosive range, miscibility with other liquids, etc. Chapter IX deals with engine tests, and the book is brought to a close with a few pages on fuel mixtures containing alcohol. It will be seen from the above résumé that the book is quite a mine of information, and can be confidently recommended not only to the specialist, but also to the general reader who is anxious to obtain enlightenment upon a number of different aspects of the important question of alcohol production for technical purposes.

**The Metallurgy of Zinc and Cadmium.** By H. P. Hofman, Ph.D., Professor of Metallurgy in the Massachusetts Institute of Technology. [Pp. xii + 341, with many illustrations and diagrams.] (New York: McGraw-Hill Book Company, 1922. Price 20s. net.)

Prof. Hofman has set himself no slight task in undertaking the preparation of a series of treatises on special metallurgy, of which this is the fourth. There are, of course, a goodly number of works on the metallurgy of zinc, but for the most part these are not now up-to-date, and so much progress has been made in recent years that there is room for a work which deals with the subject both from the chemical and technical points of view, and covers all recent developments.

Prof. Hofman naturally dwells especially upon the methods of preparing and refining the metals which are most in favour in the United States, so that certain references are likely to be of more value over there than in this country.

The book is well printed and arranged, and the author has obviously been at great pains to produce an up-to-date textbook, so that those whose work deals with the metallurgy of zinc and cadmium would do well to examine the book in detail.

F. A. M.

## CRYSTALLOGRAPHY

**Crystallography and Practical Crystal Measurement.** By A. E. H. Tutton, D.Sc., M.A. (Oxon), F.R.C.S., A.R.C.Sc. Vol. I: Form and Structure. Vol. II: Physical and Chemical. 2nd Edition. [Pp. xxxix + 1446, with 8 plates, 931 text-figures.] (London: Macmillan & Co., 1922. Price 50s. each volume.)

Crystallographers and chemists will note with satisfaction that attention has been paid by the author to most of the criticisms and suggested improvements to his well-known textbook on Crystallography and that, by an extension into two volumes, the work has become almost completely comprehensive and brought well up to date. The whole study of Crystallography has so increased its scope and utility by the far-reaching results of the application of X-rays to the investigation of crystal structure, and the bonds of alliance between Crystallography, Physics, and Chemistry so strengthened, that these subjects form by far the greater part of the new material.

A synopsis and critical survey of X-ray analysis by the methods of von Laüe, the Professors Bragg and Debye and Scherrer, with special reference to its interrelations with the 65 systems of Sohnckian points, themselves illustrated, and the 230 space groups of Schonflies, are treated excellently. A small space is also devoted to the analysis of Crystals of the Carbon Compounds, a field of research with infinite possibilities.

The subject-matter of the author's works, "Crystalline Structure and Chemical Composition" and "Crystals," is revised and incorporated into these volumes, the very fine illustrations of the latter being reproduced, and new chapters also on thermal, electrical, and magnetic properties are added. The chapters on optical properties and determinations are considerably amplified, but details are not always germane to the subject, such, for example, as the colour of birds' wings, while an account of Königsberger's determinations of opaque minerals under the microscope might be added with impunity.

Several of the weaker points of the first edition remain unchecked, and some unencouraged tendencies pervade the new material. For whom is the book written? In an attempt to make the book both technical and popular, the author has laid himself open to objections from both types of reader, but especially from students. The latter will admit that the new edition is a perfect mine of information, but how many would not have welcomed in its place a single volume with many of the superfluities deleted? We shall see how this affects each part separately.

The author admittedly avoids all "unnecessary" mathematical details, but he does not realise that a book should differ from a discourse or lecture in that emphasis should be produced rather by explanation or proof than by repetition. Simple analytical proofs, for example, of Weiss's Zone Law and the Law of Anharmonic Ratios would serve a far better purpose than the vast number of examples given of their application. The mathematical relations between the elements of symmetry would also be welcome.

In the second part of Volume I there is left little to be desired. Mallard's views on pseudo-symmetry and its relation to twinning might have been inserted, and the criticism of the Pope-Barlow theory might have been dismissed in smaller space.

Throughout the book, pre-eminence has been given to practical work, but the description of some obscure types of apparatus is often disproportionate to their importance in this connection; we think that many details from the realm of pure physics might have been replaced by reference to standard works on this subject. Indeed, from the student's point of view, the style adopted is too discursive, and more references, together with an improved index, would be more satisfactory. The chapters on crystal chemistry, however, are excellent and emphasise the true importance of this branch of crystallography, while elaborate details of the author's own contributions illustrate the methods employed. Both by his practical work and by textbooks the author has brought credit to the study of crystallography, and these volumes will assuredly be handed down to future generations as a standard work. EDGAR D. MOUNTAIN.

## METALLOGRAPHY

**Metallography.** By C. H. DESCH, D.Sc., Ph.D. Third Edition. [Pp. xi + 440, with 14 plates and 105 diagrams.] (London: Longmans, Green & Co., 1922. Price 16*s*. net.)

A BOOK by Prof. Desch and the fact that it is a third edition are sufficient assurances of reliability and excellence. His textbook on Metallography is widely known and has been used by many who have studied the subject. In the present edition the general plan and arrangement of the original are retained, but the text has been revised throughout and brought up to date. Important changes have been made in the chapter on the Physical Properties of Alloys. In the section on Hardness the Brinell test and the Ludwik modification are given, and also the recently devised method by Moore for thin sheets of metal. In the section on Electrical Conductivity there are brief accounts of recent work, including the experiments of Kamerlingh Onnes on metals at very low temperatures—about 2° above the absolute zero. The chapter on Electromotive Force and Corrosion has to a great extent been rewritten in order to cover the results of recent investigations. There are several changes in the chapter on the Metallography of Iron and Steel, the modern views on the allotropic condition of iron being included. The whole chapter gives a very concise account of our present knowledge. The Appendix, which gives a comprehensive and valuable list of systems, has been much enlarged; while throughout the book the references are complete and useful.

**The Analysis of Non-Ferrous Alloys.** By F. IBBOTSON, D.Met., B.Sc., F.I.C., and L. AITCHISON, D.Met., B.Sc., A.I.C. Second Edition. [Pp. ix + 246, with 20 diagrams.] (London: Longmans, Green & Co., 1922. Price 12*s*. 6*d*. net.)

IT is satisfactory to know that this book has proved so successful as to demand another edition. The aim of the authors was to collect those methods of analysis of the non-ferrous metals which were not only accurate but at the same time convenient and rapid. In recent years, owing to our increased knowledge of non-ferrous alloys and their heat treatment, they have been more and more widely adopted, so that a book of this kind serves a most useful purpose.

The greatly extended use of the light alloys of aluminium has made it necessary for methods of analysis of these alloys to be included in the new edition. The methods given are reliable and convenient. In the analysis of these alloys the chief difficulty is the accurate determination of the zinc content, and to meet this the authors have considered the separation of aluminium from zinc somewhat fully, a chapter being devoted to the subject. Among the additions are methods for the analysis of alloys of nickel with copper and with chromium and iron, and methods for the determination of iron and manganese in brasses and bronzes.

The methods have all been carefully selected and are clearly described. The new edition should prove useful to the works' chemist and for students taking a more advanced course of analysis.

**An Introduction to the Study of Metallography and Macrography.** By LÉON GUILLET, D. ès Sc., and ALBERT PORTEVIN. Translated by L. TAVERNER, with an Introduction by H. C. H. CARPENTER. [Pp. xvi + 289, with 562 illustrations.] (London: G. Bell & Sons, 1922. Price 30*s*. net.)

THIS book is a distinct addition to our literature, particularly on account of the excellent way in which the subject is presented. The authors state that their aim is to outline principles and to illustrate them by typical industrial examples, and throughout the work one is conscious of the practical value of the subject. The book is very well arranged and the illustrations are representative and excellent. After considering various forms of apparatus, the methods of preparing specimens, and the constitution of alloys, the authors devote a long chapter to the important subject of the relation between equilibrium diagrams of alloys and their properties and correct mechanical treatment, and then in the two subsequent chapters the industrial application of metallography to ferrous and non-ferrous metals is discussed. It is scarcely necessary to mention that alloy steels receive careful attention. The final section of the book is devoted to macrography and its industrial applications and should prove particularly useful.

The authors' definition of "Metallography" is not sufficiently comprehensive, for they are only defining micrography as applied to metallurgical specimens. Metallography is concerned with the internal structure, the constitution, and the physical properties of metals and alloys, and even includes macrography.

The research work of the authors is well known, and they have drawn freely from their papers both for descriptions and illustrations. Nearly all the statements made are generally accepted and the book can be recommended with confidence. The student will find it a well-balanced introduction to the study of metallography; also, it should prove distinctly valuable to the professional man and the engineer, as the subject is dealt with in an eminently practical manner; while for the teacher there are many helpful suggestions and much useful matter.

Great care has been taken with the translation and in retaining the character of the original, and the translator is to be commended on the excellence of his work and for the good service he has rendered to all interested in metallography.

## ZOOLOGY

**The Biology of the Sea-shore.** By F. W. FLATTELY and C. L. WALTON, M.Sc. [Pp. xvi + 336, with 16 plates and 23 text figures.] (London: Sidgwick & Jackson. Price 16s. net.)

THE habitat with which this work treats is one of perennial interest not merely because it is the traditional playground of both young and old, but because this meeting-place of land and water is the battle-ground alike of animate and inanimate nature. Here are encountered the special problems of the amphibious condition, the periodic alternation of inundation and desiccation, the effects of wave impact and all the attendant defects and advantages of mobility.

The great value of this interesting volume is that it constitutes a definite attempt to bring before the reader the relations of the animals which inhabit the tidal zone to the peculiarities of their environment. Indeed, it is one of the few real efforts to deal with a regional fauna from a definitely ecological standpoint.

The title is a trifle misleading as the flora of the tidal zone receives but scanty treatment, and even in a work more professedly zoological the very important rôle of plants, for example in modifying the mobility of the substratum, might well have received more adequate consideration. The method of presentation, too, is somewhat disconnected and, in parts, unnecessarily technical for the general reader, a defect which is enhanced by the indices, in which, for example, common species are only entered under their Latin binomials, and subject headings are all too few.

Despite these limitations, however, the suggestive text will, we feel sure, be perused with interest and profit by the general reader and the zoologist, who will alike find in these pages the source of added enjoyment when next they wander in the tidal zone. E. J. S.

**First Lessons in Practical Biology.** By E. W. Shann, B.Sc., F.Z.S. [Pp. xv + 256, with 71 figures.] (London: G. Bell & Sons, 1922. Price 5*s*. net.)

This book excellently fulfils its author's purpose, which is to introduce to the upper middle school a serious and scientific study of biology.

As presented by Mr. Shann, the study of plants, animals, insects, and fishes and their interrelations, together with the conditions governing their increase and development, proves most interesting, and while essentially practical the book is neither too elementary on the one hand nor too technical on the other.

Practically all the objects chosen for examination, dissection, and experiment are common and abundant in any rural district, while the few exceptions can easily be purchased from the usual sources.

Teachers in schools with a rural bias or where biology figures in the curriculum will find this book eminently suitable for seasonal work. The elementary treatment of variation, mutation, heredity, and Mendelism is especially noteworthy.

E. H.

**Practical Zoology for Medical and Junior Students.** By J. D. F. Gilchrist, M.A., D.Sc., Ph.D., and C. von Bonde, M.A. [Pp. xi + 344, with 105 illustrations.] (Edinburgh: E. & S. Livingstone, 1922. Price 15*s*. net.)

Since the publication of Huxley and Martin's *Practical Biology* and Marshall and Hurst's *Practical Zoology* little advance has been made on those beautifully planned and carefully thought out books.

Since their appearance, however, syllabuses have changed and facilities for teaching greatly improved; there would therefore seem to be a genuine need for a revised laboratory guide for junior students in Zoology.

A defect of some of our modern books appears to us to be in the artificial separation of gross anatomy from microscopical structure, the latter being frequently omitted altogether except in the case of those organisms, such as Protozoa or the Earthworm, for which the microscope is indispensable.

If the teaching of Zoology is to be truly morphological and not merely the gross anatomy of a series of types, the analysis of structure must be carried deeper and the microscopical characteristics studied side by side with those revealed by dissection.

No comparison of the vertebrate types, for example, is complete without a study of the structures of the skin in each, nor can the evolution of the internal, middle, and external ears be properly understood without a study of sections, however elementary. Finally, to take a third example, the cœlome and the relations of the organs thereto can be grasped in no way so easily as in a transverse section through the trunk of, say, a dog-fish embryo.

The interpretation of serial sections, a problem which the student must sooner or later encounter, can be usefully introduced at this stage, too, by the study of thick slices of the adult dog-fish.

With these ideas in mind, it is with some disappointment that we read Prof. Gilchrist's book. We find little attention given to microscopical features of the higher types. The directions for dissection are not very copious in proportion to the descriptive matter. The new diagrams have few new features. We believe that diagrams in practical textbooks should be limited to illustrating the directions for dissection. Complete diagrams are too inclined to discourage the student from observing for himself and recording things as he finds them.

The book is well printed and bound—perhaps too elegantly for the rough usage of the laboratory. The blank pages for sketches will appeal to many, although they are made of the same rather thin smooth paper as is used for the letterpress.

The book will recommend itself to students in the Cape by the inclusion among the types described of two commonly found in South Africa.

J. H. W.

## AGRICULTURE

**Farm Management: A Textbook for Student, Investigator, and Investor.** By R. L. ADAMS, Professor of Farm Management, University of California. [Pp. xx + 671, with 247 tables and 97 illustrations.] (New York: McGraw-Hill Book Company, 1921. Price 20s. net.)

UNITED STATES authorities have recognised for some time that soil fertility, crop and animal husbandry problems are but one side of the complex business of agriculture, and that the subject of actual farm management is of equal importance, though it is too frequently neglected.

The subject of Farm Management concerns the utilisation of sound principles in the selection, organisation, and conduct of practical farming operations for the purpose of obtaining the greatest possible profit. The author has undertaken a difficult task in that the matter is one of such width as to concern practically every side of agricultural activity and interest, but this has been covered in a very able and satisfactory manner. The work attempts to indicate and suggest avenues of profit under widely differing conditions, such as obtain in North America, and in this connection the information collected by the Federal Office of Farm Management has served as a valuable aid in the illustration of the text.

While a great deal of the subject-matter relates almost entirely to U.S. agricultural systems, practices, and values, there is much which can be profitably applied to the conditions obtaining in the British Isles. In this connection it is a book which caters for at least three classes. To the agricultural student it affords a general survey of the whole problem; to those about to invest money in agriculture it acts as a guide; while to those already engaged in the industry it suggests means of reforming existing practices on organised lines.

The book is divided into three sections. The first one deals with a general survey of the farming industry and the factors necessary for success. These are dealt with very fully and cover many vital subjects such as the selection of suitable farms for the various types of farming practised; the organisation of the work and distribution of capital; and a survey of the factors affecting profits.

The second section deals with farm book-keeping and accounting, and the chapters concerning agricultural costing accounts are specially helpful and show at a glance the wide variety of details which have to be considered. The tabulated results of various U.S. costing investigations lend special interest to this section. Included in this part of the book are chapters on tenancy and farm law problems as required under U.S. conditions.

The third section is devoted to a discussion of the qualifications and training necessary for the farm manager. The final chapter consists of an index to the references used throughout the text, and being arranged under the chapter headings, it therefore results in a bibliography of reference matter which lends further value to the book. HENRY G. ROBINSON.

## ANTHROPOLOGY

**Principles and Methods of Physical Anthropology.** By S. C. ROY. [Pp. vii + 181.] (Patna: Government Printing Office, Bihar and Orissa, 1920. Price Rs. 5.)

THE author of this excellent little book is the Reader in Ethnology in Patna University, which is, we gather, the first Indian University to establish anthropology as a regular subject of study. The book consists of six lectures, which were delivered in the university in 1920. All the lectures are good, but we imagine that they will have to be more numerous in the future; the first three lectures are really only introductory; and it is only in the fourth lecture that Mr. Roy gets down to the actual subject-matter of anthropology. The introductory chapters are not too long, but the latter half of the book could be expanded with advantage. The first three chapters deal with man's place in nature, the possible antiquity of man, and with the evolution theory. The exposition of evolution leaves little to be desired, and would prove equally valuable in a textbook of zoology. The last three chapters deal with the application of evolutionary theory to mankind, with speculations on the original homeland, and with the classification of existing races. The author's description of anthropological classification is clear and instructive. Mr. Roy is perhaps least strong on geological subjects. He fails to point out that Wallace's story of the relations of Africa to Eurasia has been upset by recent discoveries, and he is in error in stating that there are monkeys known from the Eocene of North America and Europe. The proof-reading has been careless, and there are numerous slips. A cephalic index cannot be "70 mm." (p. 32); and though *Pithecanthropus* was a remarkable animal, it can scarcely have been possible to weigh him in "kilometres" (p. 32). And India lies west, not east, of Burma (p. 109).

It is most gratifying to find lectures of this high standard being delivered by an Indian in an Indian University, and we shall look for rapid progress in the new school of ethnology in Patna University. A. G. T.

## MISCELLANEOUS

**The Science of Everyday Life.** By EDGAR F. VAN BUSKIRK and EDITH LILIAN SMITH. [Pp. vi + 416, with 203 illustrations.] (London: Constable & Co. Price 7*s*. net.)

THIS is an American textbook for what is known as the Intermediate School Period, and the intention of the authors is an exceedingly good one, namely, to teach science not from the purely academic point of view, where the instruction is of greatest service to those few of the pupils who are training to become specialists on the scientific side, but from the everyday point of view, and therefore for the majority of the pupils in the schools.

The authors claim that first of all courses in science should afford culture, and that this involves an intelligent understanding of the most common occurrences in daily life. Secondly, they consider that courses in science should train pupils to do with intelligent understanding and economy such tasks as are most likely to be theirs in life. With those practical views the subject is divided into five groups: the air and how we use it, water and how we use it, foods and how we use them. The remainder concerns man's control of the forces of nature, and deals with protection, homes and clothing (Group 4), and Group 5, the work of the world, under which are included work with machines, communication, transportation, and life.

In each chapter, besides descriptive matter dealing with the chief scientific principles involved, there are numerous problems and so-called individual projects to extend the work for individual pupils. In addition, at the end of each chapter, there is a list of books bearing on the subject.

English teachers will do well to study this book. It will at least widen their views as to the scope and methods of science teaching in the schools. The cost of the book may in these days make it impossible to use it as a regular school book, but a few copies in each class-room would, we feel sure, be very useful.

W. C. B.

**An Introduction to Applied Geography.** By ALEXANDER STEVENS, M.A., B.Sc. [Pp. x + 309, with 123 maps and diagrams.] (London: Blackie & Son. Price 6*s*. net.)

THIS book is intended to provide a foundation of practical geographical knowledge for navigators, land surveyors, mining engineers and prospectors.

To a teacher one could imagine that this book might be very useful as bringing his subject for him into contact with the applications of daily life, even if these are of a technical character. On the other hand, to each of the technical workers enumerated as above in the preface of the book there must be much that is very redundant on account of its elementary character. The books deal successively with geodesy, map construction and the surveying necessary to it; the reading of maps and charts; climate and weather; transport and the problems connected therewith.

The earlier chapters are the best and contain some useful and original methods of presentation of the subject, though one or two useful practical points might well have been included.

The author is unfortunately somewhat careless in his English, and the work suffers therefore in places from a lack of lucidity, which is disconcerting to the reader, and may be misleading to the student. Nevertheless, the book is well worthy of study, and moreover contains a useful appendix of practical examples. For purposes of reference an index would be a valuable addition.

W. C. B.

**Analytical Mechanics for Engineers.** By F. B. Seely, B.S., and Newton Ensign, A.B., B.S. [Pp. xiv + 486, with 454 figures.] (New York: John Wiley & Sons; London: Chapman & Hall, 1921. Price 24s. net.)

This book aims at presenting the fundamental principles of mechanics in a logical and modern form for the information of engineers.

Considerable use is made of graphical treatment alongside the analytical methods, and there are many illustrative problems of an engineering type fully and clearly worked. The diagrams are very good, and an excellent system is employed for showing vector quantities in space.

The volume deals exclusively with Statics, Kinematics and Kinetics of Solids, no mechanics of fluids being included.

An elementary knowledge of co-ordinate geometry and the calculus is assumed, but not more than is reasonable, as the book is not written for beginners of the average type.

Although several small matters call attention to the country of origin—for example the spelling of "center" and "traveling," and the allusion, when dealing with the centre of percussion, to the effect of a blow as felt at the hand when using a base-ball bat—there is nothing to detract from the usefulness of the book to a British student.

The treatment adopted is clear and logical, and special attention is paid to difficult points in mechanical engineering theory, such as the motion of links and connecting rods, the elementary theory of gyroscopic couples, inertia governors and the theory of balancing. The following small points may perhaps deserve slight criticism: In dealing with the forces in the members of framed structures, such as trusses, the forces are mentioned as stresses, whereas the rigorous use of the term "stress" for force per unit area is preferable. In the explanatory portions a rather free use is made of brackets to further explain small points, as, for example, on page 2: "namely, the actions of other bodies (forces) and the properties (inertia, etc.) of the bodies themselves," this giving a rather jerky touch to the style. Also the term "slug" and "geepound" are given—for a mass of 32·2 lb.—and the following statement appears: "The name slug is used to some extent, particularly in England." It is to be hoped that this is not the case to any extent worth mentioning.

On the whole the book may be recommended to the scientifically trained engineer to fill the gap between the academic books on mechanics and those engineering treatises where theory is either ignored or assumed.

# BOOKS RECEIVED

*(Publishers are requested to notify prices)*

The Mathematical Theory of Probabilities and its Application to Frequency Curves and Statistical Methods. By Arne Fisher. Translated from the Danish by Charlotte Dickson, B.A., and William Bonynge, B.A., with Introductory Notes by M. C. Rorty and F. W. Frankland, F.I.A., F.A.S., F.S.S. Volume I. Mathematical Probabilities, Frequency Curves, Homograde and Heterograde Statistics. Second Edition, greatly enlarged. New York: The Macmillan Company, 1922. (Pp xxiv + 289.)

The Elements of Astronomy. By D. N. Mallik, B.A., Sc.D., F.R.S.E., Professor, Presidency College, Calcutta. Cambridge: at the University Press, 1921. (Pp. viii + 233.) Price 14*s*. net.

The Climates of the Continents. By W. G. Kendrew, M.A. Oxford: at the Clarendon Press, 1922. (Pp. xvi + 387, with 149 figures.) Price 21*s*. net.

Sidelights on Relativity. By Albert Einstein, Ph.D. Translated by G. B. Jeffery, D.Sc., and W. Penett, Ph.D. London: Methuen & Co., 36 Essex Street, W.C. (Pp. 56.) Price 3*s*. 6*d*. net.

Within the Atom: A Popular View of Electrons and Quanta. By John Mills, Fellow American Physical Society. London: George Routledge & Sons, Carter Lane, E.C. (Pp. xiii + 215, with 36 figures.) Price 6*s*. net.

An Introduction to Electrodynamics, from the Standpoint of the Electron Theory. By Leigh Page, Ph.D., Assistant Professor of Physics in Yale University. London and New York: Ginn & Co. (Pp. vi + 134.) Price 10*s*. net.

Aeration and Air-Content. The Rôle of Oxygen in Root Activity. By Frederic E. Clements. Washington: The Carnegie Institution of Washington, 1921. (Pp. 183.)

Rayonnement et Gravitation. Par Félix Michaud. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. viii + 61.) Price 6 frs.

Einstein and the Universe: A Popular Exposition of the Famous Theory. By Charles Nordmann, Astronomer to the Paris Observatory. Translated by Joseph McCabe, with a Preface by the Rt. Hon. the Viscount Haldane, O.M. London: T. Fisher Unwin, Ltd., Adelphi Terrace. (Pp. 185.) Price 10*s*. 6*d*. net.

La Notion d'Espace. Par D. Nys. Bruxelles: Les Editions Robert Sand, 86 Rue de la Montagne, 1922. (Pp. 446.) Price 15*s*. net.

Véritable Interprétations Théories Relativistes. Par Maurice Gandillot. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins. (Pp. 17.) Price 80 centimes.

L'Erreur de M. Einstein l'Inacceptable Théorie: L'éther et le Principe de Relativité. Par Marcelin Dubroca, Professeur de Physique au Lycée de Dijon. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. 49.) Price 4 frs.

Les Preuves Astronomiques de le Relativité. Par E. Esclangon. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. 26.)

Éther-Électricité Relativisme: Conférence du 22 Mars 1922, à Paris. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. 40.) Price 2·50 frs. net.

Les Axiomes de la Mécanique: Examen Critique. Note sur la Propagation de la Lumière. Par Paul Painlevé. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. xvi + 110.)

Philosophy and the New Physics: An Essay on the Relativity Theory and the Theory of Quanta. By Louis Rougier. Authorised Translation from the Author's Corrected Text of "La Matérialisation de l'Énergie." By Morton Masius, M.A., Ph.D. London: George Routledge & Sons, Broadway House, Carter Lane, E.C. (Pp. xv + 159.) Price 6s. net.

La Teoria della Relativita: Volgarizzione e Critica. By Guiseppe Gianfranceschi. Milano: Societa Editrice (Vita e Pensiero). (Pp. iv + 64.) Price 5 L.

An Introduction to the Chemistry of Radio-active Substances. By A. S. Russell, M.A., D.Sc., Student and Tutor of Christ Church, Oxford. London: John Murray, Albemarle Street, W., 1922. (Pp. xi + 173.) Price 6s. net.

Vitamines and the Choice of Food. By Violet G. Plimmer and R. H. A. Plimmer, D.Sc. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. xii + 164, with 25 illustrations.) Price 7s. 6d. net.

Coal-tar Colours in the Decorative Industries. By A. Clarke, F.G.S. London: Constable & Co., 10 Orange Street, Leicester Square, W.C., 1922. (Pp. xiii + 166.) Price 6s. net.

Les Colloïdes. Par J. Duclaux. Deuxième Edition, mise à jour et augmentée. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. x + 305.) Price 10 frs.

Modern Chemical Lecture Diagrams, with Uses and Applications fully Described. By Geoffrey Martin, D.Sc., Ph.D., F.I.C., F.C.S. Assisted by J. M. Dickson, B.Sc., and Major J. W. Christelow, B.Sc., A.I.C. London: Sampson, Low, Marston & Co. (Pp. 88, with 36 original drawings.) Price 3s. 6d. net.

Proteins and the Theory of Colloidal Behaviour. By Jacques Loeb, Member of the Rockefeller Institute for Medical Research. London: McGraw-Hill Publishing Co., Bouverie Street, E.C.4. (Pp. xi + 292, with 80 text-figures.)

Life and the Laws of Thermodynamics, being the Twenty-fourth Robert Boyle Lecture, delivered before the Junior Scientific Club of the University of Oxford on June 7, 1922. By Sir W. M. Bayliss, M.A., D.Sc., F.R.S., LL.D. Oxford: University Press, 1922. (Pp. 22.) Price 1s. net.

An Inorganic Chemistry. By H. G. Denham, M.A., D.Sc., Ph.D., Professor of Chemistry, University of Capetown. London: Edward Arnold & Co., 1922. (Pp. viii + 683, with 144 figures.) Price 12s. 6d. net.

Laboratory Exercises in Inorganic Chemistry. By James F. Norris and Kenneth L. Mark. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1922. (Pp. x + 548.) Price 10s. net.

Metallography. By Cecil H. Desch, D.Sc., Ph.D., Professor of Metallurgy in the University of Sheffield. Third Edition. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. xi + 440, with 14 plates and 105 diagrams in the text.) Price 16s. net.

Essentials for the Microscopical Determination of Rock-forming Minerals and Rocks. In Thin Sections. By Albert Johannsen, Ph.D., Professor of Petrology, The University of Chicago. Chicago: The University of Chicago Press. (Pp. iv + 53.) Price $2.

Evolution of the Essex Rivers and of the Lower Thames. By J. W. Gregory, D.Sc., F.R.S., Professor of Geology at the University of Glasgow. Colchester: Benham & Co. (Pp. 68, with 10 illustrations.) Price 2s. 6d. net.

Agricultural Bacteriology. By Joseph E. Greaves, M.S., Ph.D., Professor of Agricultural Bacteriology and Physiological Chemistry in Utah Agricultural College. Philadelphia and New York: Lea & Febiger, 1922. (Pp. xv + 437, with 48 engravings.)

The Cuckoo's Secret. By Edgar Chance, M.B.O.V. London: Sidgwick & Jackson, 3 Adam Street, W.C.2, 1922. (Pp. xiv + 239.) Price 7*s.* 6*d.* net.

L'Océanographie. Par J. Thoulet. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. ix + 285.) Price 9 frs.

Birds One Should Know: Beneficial and Mischievous. By the Rev. Canon Theodore Wood. Illustrated by Roland Green, F.Z.S. London: Gay & Hancock, 35 Henrietta Street, W.C.2, 1921. (Pp. xi + 132.) Price 10*s.* 6*d.*

Foundation of Biology. By Lorande Loss Woodruff, Professor of Biology in Yale University. New York: The Macmillan Co., 1922. (Pp. xviii + 476, with 211 illustrations.)

The English Village: The Origin and Decay of its Community. An Anthropological Interpretation. By Harold Peake, F.S.A. London: Benn Brothers, 8 Bouverie Street, E.C.4, 1922. (Pp. 251, with 14 figures.) Price 15*s.* net.

Age and Area: A Study in Geographical Distribution and Origin of Species. By J. C. Willis, M.A., Sc.D., F.R.S., with chapters by Hugo de Vries, H. B. Guppy, Mrs. E. H. Reid, James Small. Cambridge: at the University Press. (Pp. x + 258.) Price 14*s.* net.

Bacteriology, General, Pathological and Intestinal. By Arthur Isaac Kendall, B.S., Ph.D., D.P.H. Second Edition, thoroughly revised. Philadelphia and New York: Lea & Febiger, 1921. (Pp. xi + 680, with 99 engravings and 8 plates.)

Infant Mortality. By Hugh T. Ashby, M.A., M.D., B.C., M.R.C.P. Second Edition. Cambridge: at the University Press, 1922. (Pp. xii + 224.) Price 15*s.* net.

Arab Medicine and Surgery: A Study of the Healing Art in Algeria. By M. W. Hilton-Simpson, B.Sc. London: Oxford University Press, 1922 (Pp. vii + 93, with illustrations.) Price 10*s.* 6*d.* net.

Analogies Mécaniques de l'Électricité. Par J. B. Pomey, Ingénieur en chef des Télégraphes. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1921. (Pp. xiv + 150.) Price 15*s.* net.

Respiration. By J. S. Haldane, M.D., LL.D., F.R.S., Fellow of New College, Oxford; Hon. Professor, Birmingham University. New Haven: Yale University Press; London: Oxford University Press, 1922. (Pp. xviii + 427.) Price 28*s.* net.

Greek Biology and Greek Medicine: Chapters in the History of Science. By Charles Singer. Oxford: at the Clarendon Press, 1922. (Pp. iv + 128, with 19 figures.) Price 2*s.* 6*d.* net.

Bioler Plant Testing: A Criticism of the Present Bioler Testing Codes and Suggestions for an Improved International Code. By David Brownlie, B.Sc. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1922. (Pp. xi + 168.) Price 10*s.* 6*d.* net.

Alternating Electrical Engineering. By Philip Kemp, M.Sc. Tech., M.I.E.E. London: Macmillan & Co., St. Martin's Street, 1922. (Pp. xi + 515, with 406 figures.) Price 17*s.* net.

The All-Electric Age. By Adam Gowans Whyte, B.Sc., Associate of the Institution of Electrical Engineers. London: Constable & Co., 1922. (Pp. xiii + 242, with illustrations.) Price 7*s.* 6*d.* net.

Reinforced Concrete: A Practical Handbook for Use in Design and Construction. By R. J. Harrington Hudson, B.Eng., A.M.I.C.E., A.M.I.Mech.E., etc., with a Foreword by E. Fiander Etchells. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1922. (Pp. xxiv + 318, with 131 figures.) Price 16*s.* net.

L'Industrie du Fer en France. Par J. Levainville, Docteur ès lettres. Paris: Librairie Armand Colin, 103 Boulevard Saint-Michel, 1922. (Pp. vi + 211.) Price 6 frs.

Steam Turbines. By William J. Goudie, D.Sc., Member of the Institute of Mechanical Engineers. Second Edition, rewritten and enlarged. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. xvii, with 329 illustrations.) Price 30*s.* net.

Elements of Radio Telephony. By William C. Ballard, Jr., M.E. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1922. (Pp. x + 132, with 50 figures.) Price 7*s.* 6*d.* net.

The Properties of Electrically Conducting Systems, including Electrolytes and Metals. By Charles A. Kraus. New York: The Chemical Catalog Company, One Madison Avenue, 1922. (Pp. 415.) Price $4.50 net.

The Misuse of Mind: A Study of Bergson's Attack on Intellectualism. By Karin Stephen, with a Prefatory Letter by Henri Bergson. London: Kegan Paul, Trench, Trübner & Co.; New York: Harcourt, Brace & Co., 1922. (Pp. 107.) Price 6*s.* 6*d.* net.

Philosophical Studies. By G. E. Moore, Litt.D., Lecturer in Moral Science in the University of Cambridge. London: Kegan Paul, Trench, Trübner & Co.; New York: Harcourt, Brace & Co., 1922. (Pp. viii + 542.) Price 15*s.* net.

The Evolution of Continuity in the Natural World. By David Russell, M.D., Director of the British Hospital, and Doctor to the British Legation, Lisbon. London: George Allen & Unwin, 40 Museum Street, W.C.1. (Pp. 278.) Price 16*s.* net.

Food Values: What They Are, and How to Calculate Them. By Margaret McKillop, M.A., M.B.E., Fellow of King's College for Women, University of London. Second Edition, revised and enlarged. London: George Routledge & Sons; New York: E. P. Dutton & Co., 1922. (Pp. viii + 171.) Price 3*s.* 6*d.* net.

The Mental Limitations of the Expert. By E. H. Hankin, M.A., Sc.D. Second Edition. Calcutta: Butterworth & Co., 6a Hastings Street; London: Butterworth & Co., Bell Yard, Temple Bar, 1921. (Pp. vii + 133.)

La Religion des Chinois. Par Marcel Granet, Chargé de Cours à la Sorbonne. Paris: Gauthiers-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. xiii + 202.) Price 8 frs.

Collected Papers on Acoustics. By Wallace Clement Sabine. Cambridge, U.S.A.: Harvard University Press; London: Oxford University Press, 1922. (Pp. ix + 27 illustrations.) Price 17*s.* net.

Chaos or Cosmos? By Edgar L. Heermance. New York: E. P. Dutton & Co., 681 Fifth Avenue, 1922. (Pp. xxi + 358.) Price $3.

The Philosophy of Humanism and of other Subjects. By Viscount Haldane. London: John Murray, Albemarle Street, W. (Pp. xiv + 302.) Price 12*s.* net.

Modern Microscopy: A Handbook for Beginners and Students. By M. I. Cross and Martin J. Cole. Fifth Edition, revised and rearranged by Herbert F. Angus. With Chapters on Special Subjects by Various Writers. London: Baillière, Tindall & Cox, 8 Henrietta Street, 1922. (Pp. x + 315, with 12 plates and 144 text-figures.) Price 10*s.* 6*d.*

The Telescope. By Louis Bell, Ph.D., Consulting Engineer, Fellow American Academy of Arts and Sciences. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4. (Pp. ix + 287, with 189 figures.)

L'Acier Élaboration et Travail. Par le Colonel Jean Rouelle. Paris: Librairie Armand Colin, 103 Boulevard Saint-Michel, 1922. (Pp. vi + 200.) Price 6 frs.

The Evolution of Knowledge. By George Shann. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4. 1922. (Pp. vii + 100.) Price 4*s.* 6*d.* net.

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# SCIENCE PROGRESS

## RECENT ADVANCES IN SCIENCE

**PURE MATHEMATICS.** By F. PURYER WHITE, M.A., St. John's College, Cambridge.

*Theory of Numbers.*—One of the most remarkable features of pure mathematics during the past ten years has been the development of the analytic theory of numbers by Hardy and Littlewood in England, and by Landau and others in Germany. The problems dealt with may be treated under three heads.

(1) The additive theory of numbers or "Partitio numerorum."

The proposition that every integer can be expressed as the sum of at most $m$ $k$th powers of integers, where $m$ is independent of the integer (but depends on $k$), is known as Waring's Problem, having been stated, apparently as an empirical result, by Waring in 1782. It had only been verified for a few special values of $k$ until 1909, when Hilbert obtained a general proof. In 1919 Hardy and Littlewood (*Q.J.*, **48**, 1919, 272–93) published an account of a new analytic method, using Dirichlet series, which led to another solution and which gives information as to the value of $g(k)$, the least value of $m$ that will do; details of the proof are given in a later paper (*Göttingen Nach.*, 1920, 33–54). Minor improvements in the proof have since been made by Landau (*ibid.*, 1921, 88–92) and Weyl (*ibid.*, 1921, 181–92). But the method also leads to another number $G(k)$, which is even more fundamental than $g(k)$; it is the least number $m$ such that *from a certain point onwards* every number can be expressed as the sum of $m$ $k$th powers. Thus every *large* number can be expressed as the sum of at most 21 biquadrates (Hardy and Littlewood, *Math. Zs.*, **9**, 1921, 14–27), whereas for smaller numbers it is possible that 37 may be required. In the Göttingen paper cited above, Hardy and Littlewood showed that $G(k) \leqslant Kk + 1$, where $K = 2^{k-1}$, but more recently (*Math. Zs.*, **12**, 1922, 161–88) they have improved this result to $G(k) \leqslant (k-2)K + 5$.

A general account of the methods employed has recently been given by Landau (*Jahresber. d. Math. Verein.*, **30**, 1921, 179–85).

An attempt to extend the method so as to apply to *algebraic* numbers has been made by C. L. Siegel (*Jahresber. d. Math. Verein.*, **31**, 1922, 22–6; *Math. Ann.*, **87**, 1922, 1–35), the first paper being a general account; the only general theorem so far known is one due to Hilbert (cf. Siegel, *Math. Zs.*, **11**, 1921, 246–75) on the decomposition of *total* positive numbers into the sum of four squares.

Another extension of Waring's Problem is to the expression of any integer as the sum of a finite number of polynomials plus a finite number of units, the total number being less than N, where N is independent of the integer. Proofs have been given by Landau (*Math. Zs.*, **12**, 1922, 219–47) and by E. Kamke (*Math. Ann.*, **83**, 1921, 85–112; *Math. Zs.*, **12**, 1922, 323–8).

(2) The Dirichlet divisor problem.

This is concerned with the order of magnitude of $D(x) = \sum_{n \leq x} d(n)$, where $d(n)$ is the number of divisors of $n$. We have

$$D(x) = x \log x + (2C - 1)x + \Delta(x),$$

C being Euler's constant, and it is a question of the order of $\Delta(x)$. Dirichlet showed that $\Delta(x) = O(x^{\frac{1}{2}})$, and Voronoï improved this in 1903 to $\Delta(x) = O(x^{\frac{1}{3}} \log x)$, while Hardy and Landau independently (1915) proved that $\Delta(x) \neq o(x^{\frac{1}{4}})$. In a Doctor's dissertation at Göttingen (1922) Rogosinski has given another proof of Voronoï's result, using the methods of Landau, involving the "lattice-points" of a circle, and Landau (*Gött. Nach.*, 1922, 8–16) discusses part of his work. J. G. van der Corput (*Math. Ann.*, **87**, 1922, 39–65) shows that $\Delta(x) = O(x^M)$, where $M < 33/100$.

A generalisation of the problem was proposed by Piltz, who discussed the sums $D_k(x) = \sum_{n \leq x} d_k(n)$, where $d_k(n)$ is the number of decompositions of $n$ into $k$ factors ($k = 2$ gives the Dirichlet problem).

In this case we get a similar remainder term $\Delta_k(x)$. A summary of the known results as to the order of $\Delta_k(x)$ is given by Hardy and Littlewood (*Proc. L.M.S.*, **21**, 1922, 39–74), who by a study of the "approximate functional equation" in the theory of the zeta-function obtain a new result. If $a_k$ denote the least number such that $\Delta_k(x) = O(x^{a_k + \epsilon})$ for every positive $\epsilon$, they prove that $a_k \leq (k-2)/k$, $(k > 3)$, it having been known before that $a_k \leq (k-1)/(k+1)$.

H. Cramér (*Arkiv för Mat.*, **16**, 1922, No. 21) obtains a series for $\Delta_k(x)$ analogous to that obtained by Hardy and Littlewood in the Dirichlet problem.

(3) The lattice-points of a right-angled triangle.

If $\omega$, $\omega^1$ are two numbers whose ratio $\theta = \omega/\omega^1$ is irrational, and $\Delta$ denote the triangle whose sides are the co-ordinate axes and the line

$$\omega x + \omega^1 y = \eta > 0$$

and $N(\eta)$ the number of lattice-points (*Gitterpunkte, i.e.* points whose co-ordinates are integral) which lie inside $\Delta$, then how accurate an approximation can we find for $N(\eta)$ when $\eta$ is large? And how does the accuracy of the approximation depend upon the arithmetical character of $\theta$? This problem (Problem A) has been treated by Hardy and Littlewood in two papers (*Proc. L.M.S.*, **20**, 1921, 15–36; *Abhl. math. Sem. Hamburg*, **1**, 1922, 212–49); it is related to another problem (Problem B) which had been considered before by Lerch, Weyl, and the authors themselves. If $[x]$ denote the integral part of $x$, and $\{x\} = x - [x] - \frac{1}{2}$, then what is the most that can be said as to the order of magnitude of the sum

$$s(\theta, n) = \sum_{\nu=1}^{n} \{\nu\theta\}$$

when $n$ is large? It is shown, in fact, in the first paper mentioned that

$$N(\eta) = \frac{\eta^2}{2\omega\omega^1} - \frac{\eta}{2\omega} - \frac{\eta}{2\omega^1} + S(\eta),$$

where $S(\eta)$ is a sum very similar to $s(\theta, n)$.

In the first paper, Hardy and Littlewood prove that $S(\eta) = o(\eta)$ for *any* irrational $\theta$; and that this is the most that is true for *every* irrational. If, however, the quotients in the continued fraction for $\theta$ are bounded, then $S(\eta) = O(\log \eta)$, and this too is a best possible result of its kind. These results are proved by elementary arguments; the remainder of the paper is based on the properties of a particular analytic function, a degenerate form of Barnes' Double Zeta-function. By its means it is shown that if $\theta$ is algebraic then $S(\eta) = O(\eta^a)$, where $a < 1$.

Various of these results were proved independently a little later by E. Hecke (*Abhl. math. Sem. Hamburg*, **1**, 1922, 54–76), who used transcendental methods, different from the above, throughout, and by A. Ostrowski (*ibid.*, 77–98, 250–1), with elementary methods.

Hardy and Littlewood's second paper contains proofs of various further results, some of which had been enunciated in an appendix to the first paper. In particular, they show that if there are constants $h \geqslant 1$ and $A > O$ such that $n^h |\sin n\theta\pi| > A$ for all positive integral values of $n$, then

$S(\eta) = O(\eta^{a+\epsilon})$, where $a = (h-1)/h$, for every positive $\epsilon$, and that this index $a$ is the best possible one. They also obtain an explicit series formula for $N(\eta)$ analogous to that given by Voronoï for the lattice-points of a rectangular hyperbola. Corresponding results in Problem B are also obtained; some of them are given in Ostrowski's paper. Allied problems are also considered, namely the series

$$f_1(s) = \Sigma \frac{a_n}{n^s}, f_2(s) = \Sigma \frac{a_n^2 - \frac{1}{12}}{n^s} \ . \ . \ . \ , \text{where } a_m = \{m\theta\},$$

and the $n$th term of the $p$th series is essentially the $p$th Bernoullian function of $a_n + \frac{1}{2}$. Hecke (*l.c.*) had shown that $f_1(s)$ is meromorphic over the whole of the complex $s$-plane, having at most a double infinity of simple poles at the points $-2k \pm 2m\gamma\pi i$, ($k$, $m = 0, 1, 2 \ . \ . \ .$), $\gamma$ being a constant depending on $\theta$; by their more elementary methods Hardy and Littlewood show that $fp(s)$ is regular if the real part of $s$ is greater than $1 - p/(1+\lambda)$. These series are also the subject of a subsequent paper by H. Behnke (*Abhl. math. Sem. Hamburg*, **1**, 1922, 252–67).

R. D. Carmichael (*Bull. Am. Math. Soc.*, **28**, 1922, 109–10) points out that the proof which he gave in 1907 of the theorem that for a given number $n$ the equation $\phi(x) = n$ has either no solution or has at least two solutions, where $\phi(x)$ is the number of numbers less than $x$ and prime to it, is not correct. The theorem, however, is probably true; the author shows at any rate that a number $x$ which is a unique solution must have at least 38 digits.

If $p$ is a prime and $q$ a factor of $p - 1$, we can obtain an equation of degree $q$ with rational coefficients each of whose roots is the sum of $(p-1)/q$ of the primitive $p$th roots of unity, no such $p$th root being included in more than one of the sums. The equation is an Abelian equation with a cyclical group. The determination of a system of relations expressing any rational function of the roots of this equation as a linear function of the roots was called by Cayley the problem of cyclotomic $q$-section. He himself worked out the complete theory for $q = 3, 4$, and Burnside in 1915 treated the case $q = 5$. O. Upadhaya (*Tôhoku Math. Journal*, **19**, 1921, 183–6; **21**, 1922, 46–50) makes a beginning for $q = 6$ by examining the cases in which the prime $p$ is 13, 19, and 31.

Other recent papers on the theory of numbers are:

R. Fueter, "Kummers Kriterium zum letzten Theorem von Fermat," *Math. Ann.*, **85**, 1922, 11–20.

H. S. Vandiver, "Note on Some Results concerning Fermat's Last Theorem," *Bull. Am. Math. Soc.*, **28**, 1922, 255–60.

T. Hayashi, "On a Certain Generalised Pell Equation," *Tôhoku Math. J.*, **20**, 1922, 252–8.
A. Bloch, "Mémoire d'analyse diophantienne linéaire," *Bull. Soc. Math. de France*, **50**, 1922, 100–10.
H. Cramér, "Sur un problème de M. Phragmén," *Arkiv för Mat.*, **16**, 1922, No. 27.
H. Cramér, "Ein Mittelwertsatz in der Primzahltheorie," *Math. Zs.*, **12**, 1922, 147–53.

On algebraic number fields :

M. Bauer, "Über relativ Galoissche Zahlkörper," *Math. Ann.*, **83**, 1921, 70–3 ; "Über die Differente eines algebraischen Zahlkörpers," *ibid.*, 74–6.
K. Reidemeister, "Über die Relativklassenzahl gewisser relativ quadratischen Zahlkörper," *Hamburg Seminar*, **1**, 1921, 27–48.
M. Bauer, "Die Theorie der $p$-adischen bzw. $P$-adischen Zahlen und die gewöhnlichen algebraischen Zahlkörper," *Math. Zs.*, **14**, 1922, 244–9.
K. Hensel, "Die Zerlegung der Primzeiler eines beliebigen Zahlkörpers in einem auflösbaren Oberkörper," *Crelle*, **151**, 1921, 200–9 ; "Zur multiplikativen Darstellung der algebraischen Zahlen für den Bereich eines Primteilers," *ibid.*, 210–12.
A. Fraenkel, "Über einfach Erweiterungen zerlegbarer Ringe," *Crelle*, **151**, 1921, 121–66.
P. Furtwängler, "Punktgitter und Idealtheorie," *Math. Ann.*, **82**, 1921, 256–79.
E. Noether, "Idealtheorie in Ringbereichen," *ibid.*, **83**, 1921, 24–66.
C. L. Siegel, "Über die Diskriminanten total reeller Körper," *Gött. Nach.*, 1922, 17–24.
E. Landau, "Der Minkowskische Satz über die Körperdiskriminante, *ibid.*, 80–2.
M. Fujiwara, "Zahlengeometrische Untersuchung über die extremen Formen für die indefiniten quadratischen Formen," *Math. Ann.*, **85**, 1922, 21–5.

On the Riemann Zeta-function :

H. Hamburger, "Über die Riemannsche Funktionalgleichung der Funktion," *Math. Zs.*, **10**, 1921, 240–54 ; **11**, 1921, 224–45 ; **13**, 1922, 283–311. See also a note by C. Siegel, *Math. Ann.*, **86**, 1922, 276–9.
C. L. Siegel, "Neuer Beweis für die Funktionalgleichung der Dedekindschen Zetafunktion," *Gött. Nach.*, 1922, 25–31.

On Dirichlet series :

F. Carson, "Sur les séries de Dirichlet," *C.R.*, **172**, 1921, 838–40 ; "Contributions à la théorie des séries de Dirichlet," *Arkiv för Mat.*, **16**, 1922, No. 18.
T. Jansson, "Über die Grossenordnung Dirichletscher Reihen," *Arkiv för Mat.*, **15**, 1921, No. 6.
E. Landau, "Über die Nullstellen Dirichletscher Reihen," *Math. Zs.*, **10**, 1921, 128–9 ; "Neuer Bewies des Schneeschen Mittelwertsatzes über Dirichletsche Reihen," *Tôhoku Math. J.*, **20**, 1922, 125–30.
L. Neder, "Über die Lage der Konvergenzabszissen einer Dirichletschen Reihe zur Beschränkheitsabszisse ihrer Summe," *Arkiv för Mat.*, **16**, 1922, No. 20 ; "Zum Konvergenzproblem der Dirichletschen Reihen beschränkte Funktionen," *Math. Zs.*, **14**, 1922, 149–58.
S. Narumi, "On the Abscissa of Summability of General Dirichlet Series," *Tôhoku Math. J.*, **20**, 1922, 188–216.
H. Bohr, "Über eine quasi-periodische Eigenschaft Dirichletscher Reihen mit Anwendung auf die Dirichletschen L-Funktionen," *Math. Ann.*, **85**, 1922, 115–22.

*Geometry.*—In the general collineation of space the vertices, planes, and edges of a tetrahedron are the only self-corresponding elements ; but there are a number of special cases. If all the points and lines of a plane $a$ are self-corresponding, so will be all the planes and rays through a point S, and the collineation is a *homology* (or *perspectivity*). If all the points of a line $u$ and all the planes through a line $v$, skew to $u$, are self-corresponding, the collineation is said to be *axial* ; but if all the points on both $u$ and $v$, and all the planes through $u$ and $v$ are self-corresponding, the collineation is said to be *biaxial* (*gescharte Kollineation*). Moreover, the collineation can only be involutory if it is a homology or biaxial. All this is perfectly well known and is to be found in the textbooks, such as Reye's *Geometrie der Lage.* But more recently (Reye, *Archiv d. Math.*, **19**, 1912, 288) intermediate cases have been examined—non-involutory collineations containing involutions of points, planes, or rays, which interchange the elements in pairs. The square of such a collineation must be a homology or axial or biaxial. For example, if a collineation interchange two planes $a_1$, $a_2$, it will interchange all the planes through their line of intersection $v$ in pairs ; the square of the collineation will leave all planes through $v$ invariant, and will therefore leave all points of a line $u$ skew to $v$ invariant. The square will thus be axial, and the original collineation may be called *half-axial.* It will contain a point involution on $u$ and a plane involution through $v$. Similarly, we may have a *half-biaxial* collineation (*halb-gescharte Kollineation*), which interchanges in pairs the points and planes of two skew lines $u$ and $v$. It will also interchange in pairs the rays of the linear congruence consisting of the double infinity of lines which meet $u$ and $v$.

S. Jolles, who collaborated in the later editions of Reye's book, has considered further cases of partial involutory collineations (*Math. Zs.*, **11**, 1921, 180–93), and in a later paper (*ibid.*, **13**, 1922, 223–62) discusses the theory of the pairing of lines in a linear congruence by means of a half-biaxial collineation. Such a relationship is determined by two of the pairs which do not belong to the same system of generators of a quadric, and the pairs of lines are reciprocal polars for all the quadrics of a pencil. There are four double rays, and we thus get three species, according as the double rays are (1) all real ; (2) two pairs of conjugate imaginary skew rays ; (3) two pairs of conjugate imaginary lines of the first kind (*i.e.* each with one real point).

Prof. H. F. Baker has edited for the London Mathematical Society (*Proc. L.M.S.*, **21**, 1922, 98–113) a remarkable paper on "Chords of Twisted Cubics," by E. K. Wakeford, the brilliant young mathematician of Trinity College, Cambridge, who was killed in the war ; he accompanies it (*ibid.*, 114–33) by elucidatory remarks and references, and by transcripts of four letters written 1914–15. The paper begins with a consideration of a particular birational transformation of space by means of the cubic surfaces through four lines ; this had already been dealt with by Hesse, Cremona, Noether, and Cayley. Mr. Wakeford then gives two theorems, due in the first place to Cremona, namely, that two twisted cubics of general position have ten common chords, and that six lines of general position are chords of six twisted cubics. The relations of these six cubics are then developed with application to Cayley's problem of the condition for seven lines to lie on a quartic surface. Prof. Baker points out the intimate connection between this theory and the theory of *apolarity* investigated by Reye. Finally, a new proof is given of Mr. Grace's theorem that if six lines have a common transversal and we take in the double six determined by any five of them the line which does not meet these five, then the six lines so obtained have a common transversal.

Using the method of defining curves in space which is developed by Hensel in his arithmetical theory of algebraic functions, H. W. E. Jung (*Math. Zs.*, **13**, 1922, 189–201) brings the formulæ which serve to determine the stationary elements of curves and developables into a form suitable for application to curves on surfaces and to developables circumscribed to a surface. In two later papers (*ibid.*, **13**, 1922, 202-16 ; **14**, 1922, 1–34) he applies these formulæ to the plane sections and tangent cones and to the cuspidal and inflexional curves of an algebraic surface.

H. von Koch was the first to consider the curve defined in the following way : A segment AB of a straight line is trisected at C and E, and an equilateral triangle CDE is constructed on CE. The segments AC, CD, DE, EB, are then treated in precisely the same way as was AB, and so on indefinitely. The vertices D, etc., of the triangles then define a curve, which can be shown to be a Jordan curve (*i.e.* its points can be put into correspondence with the points of a line) and to have no double point. F. Apt (*Math. Zs.*, **13**, 1922, 217–22) now shows that the curve is completely without tangents in a wider sense than was contemplated by von Koch ; it can have no corners ; *i.e.* if we consider separately the chords joining any point $P_0$ to following points P and to preceding points P, in neither case have they a limiting position as P approaches $P_0$.

Y. Tanaka (*Tôhoku Math. J.*, **21**, 1922, 1–2) gives a new proof of a theorem due to W. W. Taylor that the centres of the six conics touching five out of six lines lie on a conic, and that the seven conics arising thus from seven lines have three common points.

A. Kiefer (*Viertel jahrsschrift Zürich*, **67**, 1922, 15–19) deals with the problem of finding a plane such that the orthogonal projection on to it of a given tetrahedron shall be a triangle and its orthocentre.

H. J. van Veen (*Proc. Amst. Acad.*, **35**, 1922, 52–60, 61–6) examines the axes of the quadrics of revolution which pass through 4, 5, 6, or 7 given points. If 4 points are given the axes form a complex of order 3 ; if 5, a congruence of order 7 and class 2 ; if 6, a ruled surface of order 6 ; if 7, there are 4 quadrics of revolution.

G. Corte (*Rend. Lincei*, **54**, 1921, 459–62) gives an algebraic interpretation of the principle of duality applied to formulæ of incidence.

L. Berzolari (*Rend. Lincei*, **31**, (1), 1922, 421–5, 446–50) investigates the complex of the fourth degree, all of whose cones have three generators which are both double and inflexional. It originally arose from the consideration of twisted cubics which are invariant for a certain group of collineations, or more simply from three linear complexes which are in involution two by two.

P. Tortorici (*Rend. Napoli*, **28**, 1922, 51–4) proves analytically a theorem given by Segre, that if a rectilinear congruence with ruled focal surfaces establishes a correspondence between the asymptotic curves of one focal surface and the generators of the other, the first focal surface must be a quadric.

In 1908 Reye showed that the congruence of twisted cubics through 5 points can be represented by the rays of a sheaf ; J. de Vries (*Proc. Amst. Acad.*, **35**, 1922, 22–6) examines another congruence of cubics which by a cubic transformation can be represented by the rays of a bilinear congruence ; it consists of the cubics through two fixed points having three fixed chords, and has already been dealt with in another way by Stuyvaert (1902).

The *projective differential* geometry of plane curves was founded by Halphen and developed by Wilczynski ; G. Sannia (*Rend. Lincei*, **31**, (1), 1922, 450–4) develops the theory more simply by means of the absolute differential calculus with one variable ; he keeps a complete analogy with the metrical theory by defining *projective* arc, curvature and normal.

M. J. Conran (*Proc. L.M.S.*, **21**, 1922, 191–213) investigates the differential geometry of twisted curves in elliptic space ; he obtains analogues of the Frenet-Serret formulæ in the form of eighteen equations between the line co-ordinates of the tangent, principal normal and binormal, and their derivatives with respect to the arc ; he defines two curves which correspond to the tangent indicatrix, showing that all curves with two given plane curves as indicatrices are geodesics on a surface of which the geodesic geometry is Euclidean ; he examines in elliptic space the analogues of Bertrand and Mannheim curves, and he proves that there is a linear relation connecting the curvature and torsion at a point of all curves of a complex which touch one another at the point.

In the first edition of the *Théorie des Surfaces*, Darboux suggested the investigation of all algebraic curves which have constant torsion ; various authors attempted the problem, and a few years ago it was proposed as the subject of a prize essay by the Paris Académie des Sciences. The prize was shared by B. Gambier and G. Darmois, and the latter's essay is now printed (*Ann. de Toulouse*, **11**, 1919, 67–189).

W. Blaschke and K. Reidemeister (*Jahresber. d. Math. Verein.*, **31**, 1922, 63–82) give an account of the development of *affine* geometry (see SCIENCE PROGRESS, **17**, 1922, 180) ; the latest paper in Blaschke's series is by himself (*Hamburg Seminar*, **1**, 1922, 206–9) ; he improves Minkowski's inequality for the " mixed " surface area of two surfaces.

L. Berwald (*Monatshefte Wien*, **32**, 1922, 89–106) extends some of Blaschke's work to $n$ dimensions.

Other recent geometrical papers are :

A. COMESSATI, " Nuovo contributi geometrici alla teoria delle forme binarie," *Rend. Lincei*, **54**, 192, 541–51.

C. SERVAIS, " Sur les courbes du quatrième ordre et de la troisième classe," *Mém. de Liège*, **11**, pt. 2, 1922, No. 1.

L. J. SMID, junr., " Number of Circles touching Plane Curves defined by Representation on Point Apace," *Proc. Amst. Acad.*, **35**, 1922, 221–2.

E. VENERONI, " Sulle congruenze [21] de coniche che appartengono ad inversioni spaziali," *Rend. Lombardo*, **55**, 1922, 137–48.

G. SCHAAKE, " A New Method for the Solution of the Problem of the Characteristics in the Enumerative Geometry," *Proc. Amst. Acad.*, **35**, 1922, 113–17.

C. A. NELSON, " Conjugate Systems with Conjugate Axis Curves," *Tôhoku Math. J.*, **20**, 1922, 217–51.

H. LIEBMANN, " Eine charakteristische Eigenschaft der H-Netze (Orthogonalprojectionen von Haupttangentenkurven)," *Math. Zs.*, **14**, 1922, 159–68.

B. GAMBIER, " Représentation conforme avec conservation des lignes de courbure et de la valeur absolue du rapport des rayons de courbure principaux," *Ann. éc. Norm. Sup.*, **39**, 1922, 217–72.

C. DE JANS, " Note sur les courbes trochoïdales," *Mém. de Liège*, **11**, pt. 2, 1922, No. 2.

M. WEILL, " Sur les courbes rectifiables," *Bull. Soc. Math. de France*, **50**, 1922, 42–62.

T. TAKASU, " On Intrinsic Equations of Twisted Curves," *Sci. Rep. Tôhoku*, **11**, 1922, 29–41.

B. VON KERÉKJÁRTÓ, " Kurvenscharen auf Flächen," *Gött. Nach.*, 1922, 71–9.

R. FURCH, " Orientierung von Hyperflächen im projektiven Raum," *Hamburg Seminar*, **1**, 1922, 210–11.

T. Kubota, " Geodätische Linien auf konvexen Polyederflächen," *Sci. Rep. Tôhoku*, **10**, 1921, 411–16.
K. Zindler, " Über konvexe Gebilde," *Monatshefte Wien*, **32**, 1922, 107–38.
D. König, " Über konvexe Körper," *Math. Zs.*, **14**, 1922, 208–10.
T. Kubota, " Notes on Closed Convex Curves," *Tôhoku Math. J.*, **21**, 1922, 21–5.
T. Kojima, " On the Curvature of the Closed Convex Curves," *ibid.*, 15–20.
H. Rademacher, " Über eine funktionale Ungleichung in der Theorie der konvexen Körper," *Math. Zs.*, **13**, 1922, 18–27.
E. Salkowski, " Über den gemischten Flächeninhalt zweier ebenen Figuren," *Math. Zs.*, **14**, 1922, 230–5.
W. S. Ford, " On Kakeya's Minimum Area Problem," *Bull. Am. Math. Soc.*, **28**, 1922, 45–53.

**METEOROLOGY.** By E. V. Newnham, B.Sc., Meteorological Office, London.

*Hurricanes and Tropical Revolving Storms*, by Mrs. E. V. Newnham, M.Sc. (Geophysical Memoir No. 19, Meteorological Office, Air Ministry).—The storms with which the bulk of this memoir deals have different names in different parts of the world. They are " hurricanes " in the West Indies, " cyclones " in the Bay of Bengal and Arabian Sea, " typhoons " in the China Seas, " baguios " in the Philippines, and " Willy-Willies " in West Australia. They are violent atmospheric whirls round centres of low barometric pressure and have a diameter varying from 100 to 600 miles. The winds circulate round a central " eye " or calm area which averages about 14 miles in diameter, the direction of rotation being counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. Originating over the ocean in the Doldrums, generally between 8° and 12° north or south of the Equator, the vast majority move westwards at first and then turn polewards, the westward component being gradually reversed. The velocity of the wind is greatest in the region immediately adjoining the central " eye," and may considerably exceed 100 miles per hour. When passing over land their energy declines and they gradually die away. Rain falls very heavily in the region of strong winds, but in the central calm the sky is often clear. The revolving storm to which the above description applies is quite distinct from the much smaller and more violent " tornadoes " of North America, but less distinct from the " cyclones " or " depressions " of temperate latitudes. The latter are, however, larger and less intense, and seldom have a calm central area with clear skies. The true tropical cyclone, it may be noted, frequently continues its poleward movement into the region of prevailing westerly winds, rapidly losing its special characteristics, until it becomes a normal cyclonic depression of the temperate zone, moving towards the east.

Although this memoir, as has already been stated, deals primarily with this one class of storm, an account is also included of the storm-squalls and tornadoes of West Africa—a totally different class of phenomenon.

The literature dealing with tropical revolving storms is voluminous and scattered, and contains much speculation mixed up with genuine observation in a highly confusing manner. It is for these reasons very satisfactory to have all available information collected together into a single volume. The bulk of the work consists, therefore, of a comparative study of the cyclones of various parts of the world. This is preceded by an introductory note written by Sir Napier Shaw dealing with the theoretical side of the subject, an account of which it is proposed to postpone until after the facts to be explained have been set out. The same applies to a short theoretical discussion contributed by Dr. Harold Jeffreys.

*Times and Places of Occurrence of Tropical Cyclones.*—The method of grouping adopted in the memoir under discussion has practical merits to recommend it, but an alternative system will be suggested later on. The original is adhered to in the table on p. 356, which shows :

(1) The month or months of maximum frequency of occurrence (in italics).
(2) Those months in which the frequency of occurrence is at least 50 per cent. of the frequency in the maximum month.
(3) The average annual frequency.

The table is so arranged that the months noted down for the Northern Hemisphere correspond as regards season with those vertically beneath for places in the Southern Hemisphere.

As has already been mentioned, an alternative system of grouping might be adopted. In this alternative system the cyclones which originate to the north of Australia and pass across the western districts, first in a south-westerly direction, and then south-eastwards, are taken to belong to the South Pacific area. It then appears to be an accurate statement of the facts to say that cyclones appear in the summer and autumn seasons near the Equatorial margin of the trade winds on both sides of the Equator wherever those winds extend eastwards across several thousand miles of warm ocean. Three oceans provide the required conditions, namely the Atlantic, Indian, and Pacific Oceans. Of these, however, the Atlantic scarcely satisfies the required conditions south of the Equator, for the Benguela current chills the waters near the African coast, and on the Brazilian coast the requisite stretch of warm ocean is therefore not available. Thus of the six possible regions of cyclonic formation, one is unsuitable for special reasons, the other five

TABLE SHOWING PRINCIPAL MONTHS OF CYCLONIC FORMATION AND APPROXIMATE ANNUAL FREQUENCY

| — | | | | | | | | Annual Frequency. |
|---|---|---|---|---|---|---|---|---|
| West Indies, 1876–1919 . . . | — | — | — | Aug. | *Sept.* | Oct. | — | 4 |
| Bay of Bengal,[1] 1877–1912 . . . | May | — | — | — | — | Oct. | Nov. | 2[1] |
| Arabian Sea,[2] 1890–1912 . . . | — | *June* | — | — | — | *Oct.* | Nov. | [2[2]] |
| North Pacific (China Seas and Philippines), 1880–1918 . . | — | — | July | Aug. | *Sept.* | Oct. | — | 21 |
| South Indian Ocean (Mauritius region), 1848–1917 . . | — | Dec. | *Jan.* | *Feb.* | Mar. | Apr. | — | 8 |
| South Pacific (East of Australia), 1789–1891 . . . | — | — | *Jan.* | Feb. | *Mar.* | — | — | (?) |
| West Australia, 1877–1912 . . . | — | — | *Jan.* | Feb. | Mar. | Apr. | — | 1 |

being well represented. At first sight the Indian cyclones may seem to form an exception, since they occur in the south-west monsoon current and not in the trade winds, but in reality the rule holds, for the monsoon current is known to be a deflected trade wind which has followed a very long track across the warm ocean. Turning now to a more detailed consideration of the table showing the seasonal distribution of the storms of each region, those of the Indian area are seen to present unique features. They set in early, yet have their principal maximum late in the autumn. They are infrequent during late summer and early autumn—the most prolific period in all other parts of the world. This statement holds only with regard to the most severe Indian storms; if all cases of cyclonic wind circulation in which gales (force 8) occur were to be considered the figures for monthly frequency would be more in accordance with those for other regions, and would show only a more prolonged "season." In all other regions the "season" extends from slightly past the summer solstice to the middle of the autumn.

*Characteristics of Individual Storms.*—The remarks made in the first paragraph of these notes indicate how closely the tropical cyclones, once formed, resemble one another in different parts of the world. Reliable instrumental observations have not often been made near the inner area of the storm owing to the dangerous violence of the wind. Ballou[3] has, however,

[1] For the Bay of Bengal, only the severest storms are included.

[2] For the Arabian Sea, storms of quite moderate intensity are included and the figure for annual frequency is not comparable with that for the Bay of Bengal.

[3] "The Eye of the Storm," *Am. Met. Journal*, **9**, 1902, pp. 67–84.

collected some trustworthy information about the "eye" of the storm. He finds that the maximum wind speed occurs very close to this area, and that the whole inner region (the "eye" and the violent winds immediately adjoining it) is roughly symmetrical about the centre.

The central "calm" is not always complete; within it the barometer not infrequently falls towards the centre, but sometimes varies irregularly. A rise of temperature and fall of relative humidity has often been observed on land during the passage of the "eye," but not at sea.

With regard to the height of a cyclone, observations by Dallas of the crossing of storms from the Bay of Bengal to the Arabian Sea over the Western Ghats suggest that these whirls considerably exceed 3,000 feet in height. Most writers agree in believing that the whole phenomenon takes place below the level of Cirrus and Alto-stratus clouds. There is observational evidence furnished by cloud movement of an outward flow of air from the centre, but the height of such clouds being unknown, it is not possible to say exactly at what level this takes place.

The rain which accompanies the passage of a cyclone not infrequently amounts to 20 or 30 inches and is often accompanied by thunder and lightning.

**PHYSICAL CHEMISTRY.** By W. E. Garner, University College, London.

*Chemical Reactivity.*—During the last year, several papers have appeared which illustrate some of the fundamental problems of chemical reactivity, and, in a number of cases, the phenomena described are not readily explained by current chemical theory. The positive catalysis of chemical reactions by minute concentrations of water vapour has long been known, and was explained by Dixon in the case of the reaction between CO and $O_2$ as due to the formation of an intermediate substance, nascent hydrogen. H. B. Baker (*Trans. Chem. Soc.*, 1922, **121**, 568) has succeeded in showing that traces of water vapour not only influence chemical reactivity, but also play a part in the normal processes of evaporation and melting of organic and inorganic substances. In 1912 he found that the boiling points of the tri- and the tetroxides of nitrogen are raised by 44° C. and 47° C. respectively when dried over phosphoric oxides, and he has recently extended his investigations to a number of other liquids—benzene, hexane, ether, bromine, etc.—and, after several years' drying, finds that the boiling points are raised by from 30°–40° C. Benzene, for example, was found to boil at 106° C. instead of the normal value, 80° C. There is no abnormality in the boiling, and it does not appear that the phenomena are due to ordinary superheating. A striking feature of the observations is that the vapour condenses at temperatures not widely different from the true boiling point of the liquid. The condensed liquid, however, still possesses the abnormal boiling point. The restoration to the normal state may be brought about by admixture with small quantities of water, but the ease with which this change takes place varies markedly from liquid to liquid. Dried benzene could be left a day exposed to moist air, without any perceptible change occurring in its boiling point, and water could actually be distilled through this liquid without any ebullition of the benzene occurring. On the other hand, ether boiling at 83° C. was reduced to 36° C. on standing in moist air for a day. The vapour pressures of the dried liquids were also abnormal, at 20° C. the vapour pressure of ether was 374 mm. instead of 442 mm. The surface tension of dry benzene, measured by the capillary rise method, was trebled by drying for a year over phosphoric oxide, although no perceptible change could be observed in the density. This abnormal behaviour is not confined to liquids, for solids like sulphur and iodine, when strongly dried, exhibit abnormal melting points.

At present it is not possible to decide with any certainty as to the cause of the high boiling points ; a more complete examination of the physical and thermal properties of these dried liquids appears to be necessary. The evidence of surface tension indicates that the removal of the water has increased the complexity of the liquid in some manner and has reduced the concentration of the more volatile simple molecules. The part played by water in this process is still obscure.

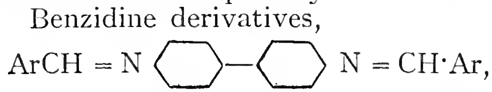
Baly and Duncan (*Trans. Chem. Soc.*, 1922, **121**, 1008), in experiments on the dissociation of ammonia by a hot platinum wire, find that the velocity of decomposition of ammonia is dependent on the rate with which ammonia is withdrawn from the cylinder. Since the addition of water to ammonia greatly accelerates the velocity of decomposition, it appears that the observed differences are due to eht varying degrees of dryness of the gas. Baly concludes that there are two forms of ammonia which differ in energy content, one of these being the ordinary reactive ammonia molecule, and the other that form which Baker found was incapable of reacting with dry hydrochloric acid. The inactive ammonia contains more of the molecules with a low energy content, and slowly passes, on standing over the liquid, or on heating, into the active gas. Hydrocarbons also increase the reactivity of ammonia ; this is interesting, since these substrnces cause perfectly dry ammonia to react with hydrochloric acid.

Another reaction in a heterogeneous system which has many points of interest is the catalytic formation of water vapour over metallic copper (Pease and Taylor, *J.A.C.S.*, 1921, **43**, 2179; and 1922, **44**, 1637). Small concentrations of oxygen markedly diminish the rate of reduction of copper oxide by hydrogen, and the rate of combination of hydrogen and oxygen over metallic copper. Between 130° and 200° C., a mixture of hydrogen and oxygen reacts partially over a copper surface to give water vapour, a portion of the oxygen in the gas being removed by the copper to form oxide, and this slowly combines with the hydrogen. Between the above temperatures the rate of formation of oxide exceeds the rate of reduction by the hydrogen, as long as oxygen is present in the gas. If, however, the oxygen is suddenly cut off, and pure hydrogen passed over the copper, an increased production of water vapour immediately takes place, and sometimes the velocity of reaction undergoes a sixfold increase. Oxygen thus behaves as a negative catalyst for the reaction, inhibiting in some manner the combination of hydrogen with the adsorbed oxygen. The explanation suggested by the authors is that the reduction of oxide occurs only at the copper–copper oxide interface. The presence of oxygen decreases the copper surface, and, at the same time, the exposed copper–copper oxide interface thus decreasing the area necessary for the reaction with hydrogen. This explanation is similar to that given by Langmuir for the reduction of the adsorbed oxygen on a tungsten or a platinum surface. Here it was suggested that the oxygen atom is removed more readily by carbon monoxide or hydrogen, when the collision occurs close to the place where the oxygen atoms are attached to the metal.

According to the present state of our knowledge of chemical reactivity, only molecules possessing energy (either kinetic or internal) above a certain minimum value are capable of entering into chemical combination. Thus the fundamental action of a positive or negative catalyst is to modify the number of active molecules in a chemical system at any time. This process occurs in homogeneous systems and, more frequently, on the surface of the third body, where the molecules are in a specially active state. In many of these processes, it is suspected that ionisation, more or less complete, is a necessary condition for chemical reaction. Not only is this held for reactions between inorganic substances, but also strong support is given at the present time to the view that in organic chemistry ionisation precedes chemical combination. The work of Kraus and others on the conductivity of organic substances in non-aqueous solvents certainly supports this view. It is thus a matter of interest to examine those reactions in which it can be shown definitely that ionisation occurs. Haber and Zisch (*Z. Physik*, 1922, **9**, 302) have investigated the ionisation which occurs when oxygen and potassium vapours are mixed. The conductivity at low pressures is considerable, so that there is no doubt that in this case electrically charged particles, possibly electrons, are liberated. By the admixture of sodium vapour with nitrogen, and burning the gaseous mixture in the halogens, he obtained flames with a temperature which was less than that at which temperature radiation becomes visible. At temperatures ranging from 350°–360° C. the flame was grey-green in colour, but above this temperature up to 473° C. the normal sodium light was obtained in such an intensity to make it possible to photograph the sodium doublet. From the intensity of the light, it was deduced that the source of the D-line is the free sodium atom, which is activated by collision with a freshly formed molecule, NaCl or $NaCl_2$, which has not yet dissipated its energy of combination. Although, in the emission of the D-line by the sodium atom, an electron is transferred only from the normal state to the first quantum orbit, a more violent disturbance may occur, such as that in the mixtures of oxygen and potassium, where the electron is raised to an infinitely large orbit.

E. B. Andersen (*Z. Physik*, 1922, **10**, 54) has studied the formation of ammonia from mixtures of nitrogen and hydrogen at low pressures under the action of a stream of slow-moving electrons, the variations in electron velocity being secured by variations in the applied electromotive force. No appreciable quantities of ammonia were produced under 18 volts. The maximum rate of formation of ammonia did not correspond with the stoicheiometric mixture of the two gases but in mixtures containing a great excess of nitrogen. This result is in agreement with the view that the first step in the production of ammonia is the ionisation of the nitrogen molecule. The ionisation of the hydrogen molecule is unnecessary.

*Liquid Crystal Formation and Chemical Constitution.*—Molecules containing long symmetrical chains of atoms readily give rise to liquid crystals, thus, in aromatic compounds, para-substituted derivatives are especially prone to this form of enantiotropy (D. Vorländer, *Zt. Angew Chem.*, 1922, **15**, 249). When the symmetry of the molecule is destroyed by the introduction of other groups, either the power of forming liquid crystals is reduced or liquid crystals become the unstable modification. Benzidine derivatives,




give crystals with a wide range of stability, but the introduction of a $CH_2$, CO, CS, S, or O group between the two benzene nuclei causes the disappearance of the liquid crystal as the enantiotropic form. These changes destroy the axis of symmetry of the molecule. When the NH group is similarly introduced, the range of stability of the liquid crystals is reduced to zero, but these crystals can exist in a metastable form below the true melting point of the compounds. This is an interesting case of monotropy. In the homologous series obtained by the successive introduction of $CH_2$ between the two benzene rings, a periodic disappearance and reappearance of the property is observed.

**GEOLOGY.** By G. W. Tyrrell, F.G.S., A.R.C.S., University, Glasgow.

*Igneous Rocks.*—N. L. Bowen has summarised his conception of the mutual relations of minerals in igneous magmas in a principle which is likely to become fundamental in petrological science ("The Reaction Principle in Petrogenesis," *Journ. Geol.*, **30**, 1922, pp. 177–98). The gist of the paper can be best given in his own words. He believes that the eutectic relation is unimportant, and that another relation between crystal and liquid phases—the *reaction relation*—is of fundamental significance. "The ordinary solid solution series such as the plagioclases may be regarded as a *continuous reaction series*, because during crystallisation each member is produced from an earlier member by reaction with the liquid, the variation in composition being continuous. There are also *discontinuous reaction series* exhibiting related characters but with discontinuous changes of composition. The series olivine-pyroxene-amphibole-mica is a prominent example among the rock-forming minerals. On the basis of these considerations the minerals making up the rocks of an igneous sequence can be arranged as reaction series, and it is the existence of such series that controls the crystallisation and differentiation of the rocks of the sequence."

In a monumental memoir by Dr. P. Niggli ("Die Leichtflüchtigen Bestandtheile im Magma," *Preissch. . . . von der Fürstlich Jablonowskischen Gesell. zu Leipzig*, **45**, 1920, pp. 272) magmas are treated from the point of view of their composition as mixtures in various proportions of easily volatilised and difficultly volatilised constituents. It is impossible to summarise adequately a work of this kind. There is a thorough review of systems composed of the above-mentioned constituents. Then natural magmatic processes are treated in relation to their dependence upon the volatile constituents. Finally, there is a review from this standpoint of the petrographical literature dealing with plutonic, laccolithic, and volcanic rocks, contact metamorphism, pneumatolytic ore deposits, and pegmatites.

In a paper on the development of pressure in magmas as a result of crystallisation, G. W. Morey (*Journ. Wash. Acad. Sci.*, **12**, 1922, pp. 219–30) shows that in a system such as $KNO_3$ and water, consisting of volatile and non-volatile constituents, crystallisation takes place at a temperature lower than the f.p. of the pure non-volatile salt by an amount corresponding to the quantity of volatile substance present, and that the three-phase pressure increases rapidly as the temperature is lowered. Hence, in magmas consisting of silicates and water, in which considerable pressure is required to retain the water in solution, a small amount of crystallisation will result in a large increase of pressure. Under suitable conditions a volcanic outburst might take place as a result of this development of pressure. The production of a " bursting pressure " through crystallisation in magmas was premised in W. H. Goodchild's memoir entitled " The Evolution of Ore Deposits from Igneous Magmas," published in the *Mining Magazine* (London) for 1918, a paper of outstanding importance outlining bold petrogenic theories, which have, however, attracted little attention in this country, and apparently none at all in America (see SCIENCE PROGRESS, January 1919, p. 375).

Pure artificial orthoclase has been prepared by G. W. Morey and N. L. Bowen (*Amer. Journ. Sci.*, (5), **4**, 1922, pp. 1–21). With the use of this material orthoclase has been shown to be an example of incongruent melting, breaking up at 1170° C. into leucite and a liquid. As the temperature is raised leucite finally disappears at 1530° C. Thus the interval of incongruent melting is very large, *viz.* 360° C. The establishment of this fact is of great petrogenetic importance, since it shows that under suitable conditions leucite can separate from an orthoclase melt, which may later on deposit free silica. If the early leucite crystals are removed from immediate contact with the liquid by any means, it will become possible for phenocrystic leucite to exist in a ground mass containing quartz, as in the leucite-granite-porphyry of Brazil. Furthermore, this phenomenon explains the clear gravitational association of leucite rocks with quartz-syenite, etc., in such masses as that of L. Borolan, Sutherlandshire.

Dr. H. H. Thomas has fully described the xenolithic material that occurs in some tholeitic minor intrusions of Tertiary age in Mull (*Quart. Journ. Geol. Soc.*, **78**, pt. 3, 1922, pp. 229–60). Both cognate and accidental inclusions are present ; the former consist of bytownite and pyroxene aggregates ; the latter are of siliceous and aluminous composition. The siliceous xenoliths are characterised by the development of tridymite ; but the most complex and interesting mineralogical developments are found in the aluminous xenoliths. Corundum (sapphire), spinel, sillimanite, cordierite, and anorthite are the most frequently occurring minerals. They are due to the permeation of an aluminous sediment by magmatic matter, especially by lime, ferrous iron, and magnesia.

The alteration is held to be of a deep-seated character, and is believed to have been produced by the reaction of tholeitic magma upon the lining of its basin. The mutual relations of the xenolithic minerals are closely dealt with in the light of recent work on fused mixtures of silicates and oxides. The temperatures concerned in the metamorphism of the xenoliths are shown to have been between 1400° C. and 1250° C.

Following hard upon Dr. Thomas's investigation of the actual behaviour of certain kinds of xenolith in basic magmas comes Dr. N. L. Bowen's theoretical work on the same subject, based upon the reaction principle, and the observed phenomena in melts of definite composition ("The Behaviour of Inclusions in Igneous Magmas," *Journ. Geol.*, **30**, 1922, pp. 513–70). The two researches are mutually supporting. Bowen shows that in the great majority of cases little or no superheat can be developed in magmas. The exceptions are in basic magmas and at long-lived volcanic centres where exothermic gas reactions may provide some superheat. Hence the phenomena that take place when inclusions are immersed in liquid magma are not solutions in the narrow sense, but chemical reactions between the liquid and solid that mostly follow and do not disturb the normal course of crystallisation. Only the relative proportions of the resulting products are altered.

An important point which is demonstrated is that a liquid saturated with one member of a reaction series is effectively supersaturated with all preceding members of that series. It cannot dissolve such members if they are added anew to the liquid, but can only react with them to convert them into the members with which it is saturated. Granite magma cannot dissolve olivine, for instance; but it will convert the olivine into biotite and hornblende, members of the reaction series with which it is saturated.

The behaviour of igneous and sedimentary inclusions of various kinds in basaltic and granitic magmas is discussed at length. It is concluded that magmas may incorporate considerable quantities of foreign matter both by reactive solution and reactive precipitation. It is thought doubtful, however, whether the presence of foreign matter is ever essential to the production of any kind of differentiate. The inclusions may accentuate the normal differentiation tendencies which are possible in a given magma, and which would proceed in any case without the intervention of foreign matter.

Prof. S. J. Shand's presidential address to the Geological

Society of South Africa on "The Problem of the Alkaline Rocks" (*Proc. Geol. Soc. S. Africa*, 1922, pp. xix–xxxii) is noteworthy for the suggestion that alkaline rocks arise as much from deficiency of alumina as of silica in magmas, and that three groups of alkaline rocks may therefore be distinguished according to whether alumina or silica, or both, are deficient relatively to the alkalies. He constructively criticises the views of Jensen, Daly, Smyth, and Bowen, on the origin of alkaline rocks, and brings forward a hypothesis which appears to synthesise the views of these investigators; namely, that alkaline rocks as a whole are developed where magma, for any reason, becomes abnormally rich in volatile constituents. Shand holds that syntexis of sedimentary rocks is not required to explain the formation of over-saturated alkaline rocks; but that Daly's hypothesis of reaction with limestone is proved for many occurrences of under-saturated alkaline rocks.

Inspired by Bowen's work on the alnöite of Cadieux, Montreal (see SCIENCE PROGRESS, April 1922, p. 548), K. H. Scheumann has published an excellent paper on the petrogeny of the numerous melilite-bearing types of alkaline lamprophyres, such as polzenite, bergalite, etc., which have recently been described from Bohemian and German localities ("Zur Genese alkalisch-lamprophyrisch Ganggesteine," *Centr. f. Min. Petr. Pal.*, 1922, pp. 495–520, 521–45). Bowen's reaction principle is applied throughout, melilite being formed by the reaction of an alkaline residual liquor upon pyroxene, biotite from olivine, etc. With the absorption of lime (proved by incompletely digested limestone xenoliths) monticellite is formed from olivine. A useful distinction is made between rocks of *accumulative* type, due to the aggregation in any way of early-formed crystals; and *fusive* types, in which there has been more or less complete reaction between the early minerals and the alkaline residual melt.

A paper by Per Geijer on "Problems suggested by the Igneous Rocks of Jotnian and Sub-Jotnian Age" (*Geol. Fören. Stockholm Förh.*, **44**, 1922, 411–43) brings forward some important reflections on the subject of petrographic provinces. Geijer shows that, outside the trench of weakness affected by Caledonian orogeny, the igneous rocks from post-Archæan times to the Cainozoic in the great Fenno-Scandian resistance block have a certain community of character. They are of a distinctly alkaline cast. He suggests that this fact illustrates the Harker-Becke-Prior hypothesis of the connection between petrographic provinces and types of earth movement. The presence of alkaline rocks in a block-faulted resistant massif, such as Fenno-Scandia, does not necessarily mean that an alkaline magma underlies the region, but merely that the conditions of magmatic differentiation necessary for the production of alkaline types are more often realised in regions of this structural character than in folding zones.

In continuation of former work R. Brauns has now published a thorough investigation of the phonolitic rocks of the Laach region (Eifel) (*Neues Jahrbuch f. Min. Beil.-Band.*, **16**, 1922, pp. 1–116). This area includes the well-known leucitophyre of the Rieden, which appears under the unfamiliar name of *selbergite*, on the ground that it is really a dyke rock, not a lava, to which form the term leucitophyre is correctly applied. Selbergite is therefore nosean-leucite-tinguaite-porphyry; *schorenbergite*, similarly, is a new name given to a nosean-tinguaite-porphyry. The mineralogical and textural differences between these rocks and the corresponding effusive forms seem scarcely worth the bestowal of new names. Numerous inclusions of plutonic rocks of alkaline character occur as fragments in the tuff vents of the Eifel. Among them are nepheline-syenite, nosean-syenite, and cancrinite-syenite, as well as calcite-syenite, in which the carbonate is regarded as a primary pyrogenetic mineral. *Riedenite* is a new name given to a nosean-biotite-pyroxene-rock occurring in this way. Its chemical affinities appear to be with theralite and shonkinite.

Prof. S. J. Shand has described the geological and petrological relations of the small syenitic mass of Leeuwfontein, Pretoria district (*Trans. Geol. Soc. S. Africa*, **24**, 1921, pp. 232–49). It forms an elliptical outcrop occupying 2½ square miles, and the igneous complex is intruded into quartzites of the Pretoria Series. The mass represents the differentiated rocks of an old volcanic vent. Soda-trachyte was first erupted; and this rock was successively broken by confocal plugs of white syenite (akerite), red syenite (umptekite), and nepheline-syenite. This vent is practically in line with at least three others of similar characters, forming a series akin to that of the Monteregian Hills, near Montreal. A welcome feature of the petrographical part of the paper is the suggested extinction of four unnecessary rock names, *viz.* leeuwfonteinite, hatherlite, pilandite, and pienaarite, which have been applied to various phases of this complex.

An important petrographical memoir by D. Rotman has belatedly come to hand from Roumania ("Das Eruptivmassiv von Greci, District Tulçea, Dobrogea, Petrog. Studie," *Anuar. Inst. Geol. Romăniei*, **7**, (1913), Buçarest, 1917, pp. 249–425). It is an intensive study of a typical Cordilleran magma, injected into the Devonian and Permo-Carboniferous sediments of the Dobrogea fold mountains. Two series of rocks are distinguished: an amphibole-granite—granodiorite—tonalite series; and a mica-poor granite—gabbro series. These are regarded as the products of the primary differentiation of an *Urmagma*, and have themselves suffered a secondary differentiation. A final phase was the injection of numerous varieties of aplite into the consolidated mass. In form the intrusion is believed to be intermediate between a laccolith and a batholith, and the act of intrusion was intimately connected with the folding of the adjacent strata. The description suggests a large type of phacolith (Harker). The paper is further noteworthy for the large number of analyses of gases included in the igneous rocks.

One of the most important results of P. Eskola's detailed memoir "On the Eclogites of Norway" (*Vidensk. Selsk. Skr. I. Math.-Nat. Kl., Kristiania*, 1921, No. 8, p. 118) is that the eclogites found in the banded igneous gneisses are not segregations from the magma, but fragments detached from large bodies of eclogite rock. They have, however, originated under the same stress conditions as the gneiss, and show consanguinity indicating genetic connection with the latter rock. In bulk composition the eclogites are identical with the "dark inclusions" so common in many granites and gneisses. The banded eclogites in the olivine-rock of Søndmøre are also of igneous origin and are genetically connected with their country rock. Both types are consanguineous with the labradorite rocks common in the Bergen district.

H. von Eckermann has completed an intensive study of the rocks and minerals of Mansjø Mountain (Helsingland, Sweden) (*Geol. Fören. Stockholms Förh.*, **44**, 1922, pp. 203–410). The area consists of synclinally-folded crystalline limestones, pyroxene-gneiss, and paragneisses, intruded by amphibolites. There are also post-folding intrusions of magnesium- and iron-rich peridotites, harzburgite, and eulysite. The contacts of these ultrabasic rocks with the surrounding metamorphic rocks is marked by metasomatic action resulting in the production of various types of "skarn." The latest intrusion is a highly alkaline microcline granite, whose pegmatites intrude the crystalline limestone, and have caused the formation of a wonderful series of contact minerals, including grossularite, vesuvianite, chrondrodite, phlogopite, apatite, and wollastonite, with many others. This has been accomplished through the transfer of magnesia and alumina to the limestone by the agency of halogen emanations.

The pre-Devonian basement complex of central Spitsbergen, described by the writer (*Trans. Roy. Soc. Edinburgh*, **53**, pt. 1, 1922, pp. 209–29), consists of a series of slates, quartzites, and calcareous hornfels, having the same strike as, and lithologically identical with, the type Hecla Hook rocks of Treurenberg Bay. These are associated with a much more highly metamorphic series consisting of paragneisses, garnetiferous-mica-schist, hornblende-gneiss, and crystalline limestone, which may possibly be older than the Hecla Hook (Ordovician). The Hecla Hook formation is intruded by a remarkable group of potassic igneous rocks, including a range of types from potash-granite, through augite-biotite-syenite, to shonkinite. A simple linear relation in the mineral proportions suggests that crystallisation-differentiation under gravitational influence has been operative.

F. W. Clarke and H. S. Washington (*Proc. Nat. Acad. Sci. U.S.*, **8**, 1922, pp. 108–15) have recently completed the computations of the average chemical composition of the igneous rocks of various countries, of the continents, and of the earth's crust, based on the data assembled in Washington's recent collection of igneous rock analyses. In computing the average composition of a 10-mile thick crust the lithosphere is assumed to be made up of igneous rocks, 95 per cent.; shale, 4 per cent.; sandstone, 0·75 per cent.; and limestone, 0·25 per cent. By assuming that the 10-mile crust is composed entirely of igneous rocks, the only difference produced in the resulting composition affects, on the whole, the second figure of decimals in the percentages.

T. Crook has adversely criticised Clarke and Washington's method of determining the average chemical composition of the earth's crust (*Nature*, August 19, 1922, pp. 253–5) on the grounds that no allowance is made for the relative magnitudes of the kinds of rock composing the various averages used. Furthermore, he claims that since the granitic portion of the lithosphere is largely restricted to the continents and is probably underlain at a small depth by a basaltic shell, and that the oceans are also probably underlain by basalt, Clarke and Washington's method seriously under-estimates the basicity of the crust even down to depths of 10 miles. The average igneous rock, too, must be of basic composition, instead of intermediate as often claimed.

*Sedimentary Rocks and Structures.*—In a paper on the impressions made by bubbles, raindrops, and other agencies on the surfaces of strata, W. H. Twenhofel (*Bull. Amer. Geol. Soc.*, **32**, 1921, pp. 359–72) shows, by experiment, that impressions which may be taken for raindrop marks may originate in at least nine different ways, namely: (1) Impressions really made by raindrops; (2) hail impressions; (3) drip impressions; (4) spray and splash impressions; (5) impressions made by floating bubbles in shallow water which become anchored to the bottom by mud films; (6) impressions due to bubbles of trapped air rising through mud in flooded areas; (7) impressions due to rising and falling of bubbles in very shallow waters; (8) impressions due to bubbles arising from the decay of organic matter in mud ; (9) pit and mound structures due to small upward currents in rapidly flocculated sediments. Valuable illustrations of these types of impressions are given, and the conclusion is arrived at that impressions due to falling rain are only a small percentage of structures usually so described. Hence there is need for caution in the interpretation of deposition conditions based on the occurrence of so-called raindrop impressions.

From observations on present-day shores P. E. Raymond (*Amer. Journ. Sci.* (5), **3**, 1922, pp. 108–14) has accumulated good evidence that the trails on sandstones and shales usually ascribed to annelids are really made by gastropods and other short-bodied animals. Winding irregular trails with sharp turnings must have been made by short, not elongated, animals. The trails of the common earthworm are nearly straight, or in curves of long radius. These observations are applied to certain trails described by Walcott in pre-Cambrian rocks.

The preservation of trails requires rather unusual conditions, particularly that the mud shall contain sufficient cement, such as calcium carbonate, iron oxides, or hydrous silica, to set quickly on exposure. On the basis of Raymond's observations S. Powers (*ibid.*, pp. 101–7) describes certain marks on Pennsylvanian Sandstones in Texas as the trails of gastropods.

Other notable papers on sedimentary rocks and structures are the following :

W. A. Johnston, " Sedimentation in the Fraser River Delta," *Canada Geol. Surv. Mem.*, **125**, 1921, p. 46.

W. A. Johnston, " The Character of the Stratification in the Recent Delta of Fraser River, British Columbia," *Journ. Geol.*, **30**, 1922, pp. 115–29.

C. K. Wentworth, " A Scale of Grade and Class Terms for Clastic Sediments," *ibid.*, pp. 377–92.

G. D. Hubbard, " Colloids in Geologic Problems," *Amer. Journ. Sci.* (5), **4**, 1922, pp. 95–110.

W. A. Tarr, " Cone-in-Cone," *ibid.*, pp. 199–213.

W. A. Tarr, " Syngenetic Origin of Concretions in Shale," *Bull. Amer. Geol. Soc.*, **32**, 1921, pp. 373–84.

F. A. Wilder, " Some Conclusions in Regard to the Origin of Gypsum," *ibid.*, pp. 385–94.

A. N. Winchell and E. R. Miller, " The Great Dustfall of March 19, 1920," *Amer. Journ. Sci.* (5), **3**, 1922, pp. 349–64.

R. Thiessen, " Compilation and Composition of Bituminous Coal," *Journ. Geol.*, **28**, 1920, pp. 185–209.

G. V. Wilson, " The Ayrshire Bauxitic Clay," *Mem. Geol. Surv. Scotland*, 1922, p. 28.

A. Gilligan, " Petrography of the Millstone Grit of Yorkshire," *Quart. Journ. Geol. Soc.*, **75**, pt. 4, 1920, pp. 251–94.

P. E. Raymond, " The History of Corals and the ' Limeless ' Ocean," *Amer. Journ. Sci.* (5), **2**, 1921, pp. 343–7.

**BOTANY.** By E. J. Salisbury, D.Sc., F.L.S., University College, London.

*Ecology.*—The contradictory results that have been obtained by various workers with regard to the effect of varying transpiration rates on the ash content of the plant, has led Muenscher (*Amer. Jour. Bot.*, pp. 311–29, 1922) to test the matter on Barley grown in culture solutions, the rate of transpiration being reduced by either (1) increasing the atmospheric humidity; (2) decreasing the illumination; or (3) increasing the concentration of the nutrient medium. Decrease of the rate of transpiration to less than one-half by the first method caused but little variation in the ash content. A slight reduction was effected by the third method, but when the reduced transpiration was brought about by the second method, which also reduced assimilation, the ash content was proportionately diminished.

A forest consisting of *Pinus contorta* with an undergrowth of *Ledum grœnlandicum* and *Gaultheria shallon*, which has become established on an old *Sphagnum* bog, is described by G. B. Rigg (*Ecology*, vol. iii, p. 207). The substratum is 6–12 inches of pine needles resting on about 12 inches of *Sphagnum*, and followed by a fibrous peat with a high water content. The succession to forest appears to have been hastened by drainage, and the clearance of the surrounding area.

The relation of maritime soils to their vegetation is the subject of a paper by Salisbury (*Ann. Bot.*, vol. xxxvi, pp. 391–431), in which it is shown that in both dune soils and those of shingle beaches the reaction tends to become more acid with increasing age and there is a diminution of carbonates and an increasing organic content. In the dune soils the relation between the organic content and the water capacity is a close one. In the salt marshes also there appears to be an increase of organic content with age, but here the duration and frequency of tidal inundation seems to be the chief factor to which the vegetation responds.

On the dunes and shingle beaches the sequence of phases in the vegetation would appear to be correlated with the edaphic sequence with respect to soil stability, reaction, carbonate and organic contents. The acid reaction is a result of the organic material present and varies with the source and the phase of decay which this has attained.

*Geographical Distribution, etc.*—In an account of the flora of the Pliocene beds of the Rhone valley corresponding in age to the Coralline Crag and Norwich Crag, G. Depape makes an important contribution to the geographical distribution of the past and its relation to that of the present (*Ann. d. Sci. Nat. Tx.*, pp. 73–265). Seventy species are enumerated, of which

55 occur in the upper plaisancien of St. Marcel. Of this total 47 are probably living species, and 26 constituents of the existing flora of the region (*e.g. Populus tremula, Quercus sessiliflora, Castanea vesca, Buxus sempervirens*), its Mediterranean element is exemplified by *Quercus lusitanica, Platanus orientalis, Ilex balearica, Nerium oleander*, etc.

A North American element is presented by *Juglans cinerea, Liriodendron tulipifera, Sassafras officinale*, and *Sequoia sempervirens*, whilst the Canary Island flora is represented by *Laurus canariensis, Celastrus cassinoides, Ilex canariensis, Persea indica*, and *Oreodaphne fœtans*. The flora of the East is also represented by *Torreya nucifera, Glyptostrobus heterophyllus, Ginkgo biloba, Quercus serratus, Buettneria aspera*, and species of *Cinnamomum*. From a consideration of the present requirements of these species the author concludes that the climate at that period was probably comparable to that of the southern part of the United States. Several of the fossil species are identical with those of the cretaceous in Greenland and of the eocene deposits in the Paris basin. It is suggested that these indicate a southern emigration.

Matthews has made a study of the Perthshire flora from the point of view of the age and area hypothesis (*Ann. Bot.*, vol. xxxvi, pp. 322–7), and finds it to be generally applicable to a county flora, though, as was to be expected, the relic arctic-alpine flora does not conform to the general principle.

*Cytology.*—Heilborn, in a brief paper on the chromosome number in the genus *Carex* (*Svensk. Bot. Tid.*, pp. 271–4, 1922), corrects some earlier observations, and adds data respecting other species which show the great variability of chromosome number within this genus. There appear to be 9 chromosomes in *Carex pilulifera* ; 15 in *C. ericetorum* ; 15 or 16 in *C. vaginata* ; 16 in *C. panicea* ; 19 in *C. montana* ; 26 in *C. digitata* and *C. dioica* ; 27 in *C. atrata* ; 28 in *C. Halleri* ; 31 in *C. caryophyllea* ; 32 in *C. pallescens* ; 34 in *C. vulpina* ; 35 in *C. flava* ; 36 in *C. riparia* ; 35 in *C. rostrata* ; 40 in *C. caespitora* and *C. Hudsonii* ; 41 in *C. vesicaria* ; 42 in *C. gracilis* and *C. Goodenovii*. It would seem, therefore, that the chromosome number bears no relation to the taxonomic affinity, for whilst closely related species (*e.g. C. pilulifera* and *C. montana*) may have very different chromosome numbers, two such very widely separated species as *C. dioica* and *C. digitata* have the same number.

To the list of plants in which cell division of the Angiosperm microspore takes place by furrowing, in place of cell plate formation, C. H. Farr has added *Nelumbo lutea*. The fact that this type of division has also been found in *Nicotiana, Primula, Tropæolum*, various Compositæ (*Ambrosia, Chrysanthemum, Helianthus, Lactæa*), *Magnolia* and

*Sisyrinchium* indicates a widespread occurrence of no taxonomic significance.

*Genetics.*—The effect of selection within pure lines has again been attempted, this time with *Pestalozzia Guepini*, one of the fungi imperfecti, as the subject of investigation. The selections were made according to two plans. In the one series the selection was based on the divergence in the progeny means so that the usual visible characteristics were ignored and the performance of the progeny used as the criterion of selection. In the second series the usual method of selection by visible characters was adopted. The characters used were length of spore and length of spore appendage, the selection being maintained for 10 and 25 generations in one experiment, and 10 and 6 generations in a second (*Genetics*, pp. 142–201, 1922).

Neither method was effective in establishing a distinct line within the pure strain. Mutations were observed, though infrequent, and it is interesting to note that a mutation with exceptionally long spore appendages appeared in a pure line which was being selected for diminished length of spore appendages, and it is pointed out that mutations in the same sense as the selection might well account for the positive results obtained by some workers.

*Floral Morphology* species of the genus *Marcgravia* have been regarded as affording striking examples of a pollination mechanism adapted to the agency of humming birds which visit the flowers for the sake of the sugary fluid in the pitcher-like bracts borne below the flowers, or for the sake of the flies which visit these pitchers. Bailey (*Amer. Jour. Bot.*, pp. 320–84, 1922) has studied two species of this genus, described as new, in the field, and finds no grounds for believing the flowers to be pollinated by birds which approach the inflorescences from above even in species with downwardly directed flowers. On the contrary, his observations and experiments lead him to the conclusion that both the species studied, and probably also *M. umbellata*, are self-pollinated.

## PLANT PHYSIOLOGY.

By Cyril West, B.A., D.Sc., Low Temperature Research Station, Cambridge (Plant Physiology Committee).

*After-ripening, Dormancy, and Methods of Terminating the Dormant Period of Seeds.*—During the last two or three years much attention has been directed to the subject of after-ripening and dormancy of seeds, especially by American botanists. But although an intensive study has been made of the chemical and physical changes which take place in dormant seeds of various plants, not only in the embryo itself, but also in the structures which make up the seed coat, we are not yet in a position to state definitely for any given plant the factor or factors which bring about the phenomena observed.

A comparative study of the conditions under which the seeds of two closely related species of *Acer* will germinate has been carried out by H. A. Jones ("Physiological Study of Maple Seeds," *Bot. Gaz.*, lxix, 1920, p. 127). Seeds of *Acer saccharum* March and *Acer saccharinum* Linn. were chosen for investigation because they show a striking contrast in season of maturity, reaction to external conditions, chemical composition, and in their general physiological behaviour. The seeds of the former are matured in the autumn and require a definite period of after-ripening before germination can take place. The optimum temperature for the after-ripening of these seeds is approximately 5° C., and a free supply of oxygen and moisture is essential. During the process of after-ripening an increase in free reducing sugars, catalase activity and peroxidase activity was observed. In the case of *A. saccharinum*, on the other hand, the seeds ripen in the spring and will germinate almost immediately upon a moist substratum, but lose their viability when the water content is reduced to about 30 per cent. At low temperatures, however, if stored over water these seeds retain their viability for a considerable period.

The germination of juniper seeds has always presented many difficulties to nurserymen. In two recent papers D. A. Pack ("After-ripening and Germination of Juniperus Seeds," *Bot. Gaz.*, lxxi, 1921, p. 32; "Chemistry of After-ripening, Germination, and Seedling Development of Juniper Seeds," *Bot. Gaz.*, lxxii, 1921, p. 139) presents the results of an exhaustive study of this subject and shows that the seeds of *Juniperus* germinate readily after being maintained at a constant temperature of 5° C. for about 100 days to allow for the after-ripening of the dormant embryo. Accompanying after-ripening the following changes, amongst others, were observed: (1) An increase in the hydrogen-ion concentration of the embryo; (2) an increase in titratable acid; (3) a decrease in the amount of stored fat and protein; (4) an increase of sugar content; (5) the translocation of fat from the endosperm to the embryo; (6) a slight increase in the rate of respiration; (7) an increase in the value of the respiratory quotient; and (8) a marked increase of catalase activity. The optimum temperature for the germination of *Juniperus* seeds was also found to be 5° C. In the course of this investigation it was discovered that when the seeds which had completed their after-ripening processes at 5° C. were transferred to temperatures above 15° C. they were thrown into a state of secondary dormancy.

A satisfactory solution of the problem as to why the seeds of annual plants germinate in the spring after lying dormant on the ground during the winter months has yet to be found. A. Lumière has published a series of articles ("Le Revéil de la Terre," *Comptes Rendus de l'Acad. des Sc.*, 1920, p. 868; "Action nocive des Feuilles Mortes sur la Germination," *ibid.*, 1921, p. 232; "Le Rythme saissonier et le Revéil de la Terre," *Rev. gén. de Bot.*, xxxiii, 1921, p. 545) dealing with the results of an attempt to discover a controlling factor of this seasonal rhythm in vegetation apart from any direct effect of such obvious environmental factors as temperature, light, and rainfall. In these three papers the author has shown conclusively that the soluble products of fallen leaves, debris of annual plants, etc., act as powerful reducing agents and may inhibit the germination of seeds, and has developed the interesting hypothesis that these substances have an important rôle in the seasonal periodicity of vegetation under natural conditions. For the normal germination of most seeds a free supply of oxygen is necessary. Hence it becomes evident that any reducing substance which may be dissolved out of rotting leaves and other decaying vegetation and remain in the soil for a certain period will tend to absorb oxygen and deprive the seeds of a supply sufficient for germination. Sooner or later these soluble substances either become oxidised, a change which is accelerated by the rising temperature of spring, or are washed out of the superficial soil by rain. When either result is achieved the seeds readily germinate. As evidence in support of his theory Lumière records the results of a number of experiments, from which the following are a selection. In one experiment leaves of various plants were soaked in rain-water immediately after they had fallen and the extract was employed in dilute solution to water the soil in which barley grains had been sown. The germination of the seeds was completely inhibited.

In another experiment similar leaves were left for three months freely exposed to the air, during which interval they were acted upon by various micro-organisms, amongst which a species of *Bacillus* was prominent. At the end of this period the decaying vegetable matter was extracted with water. In both cases the extract was found to possess powerful reducing properties and to inhibit the germination of barley seeds.

In a third experiment a sample of soil from open ground was taken in November and divided into two similar lots. One of these was repeatedly washed with distilled water in order to dissolve out soluble substances, whereas the other was simply kept moist with distilled water. After a few days at the temperature of the laboratory seedling plants appeared on the former, but not on the latter, thus indicating that the repeated washing with distilled water had eliminated some soluble substance which inhibited germination. The water-extract of a sample of similar soil was found likewise to inhibit germination, but that it did not exercise any toxic effect upon the seeds was proved by the fact that they germinated readily after they had been rinsed thoroughly with water.

The dormancy or delayed germination which is exhibited by the seeds of certain plants when sown in an immature condition immediately after removal from the parent plant has been dealt with by F. Kidd and C. West (" The Rôle of the Seed-coat in Relation to the Germination of Immature Seed," *Ann. Bot.*, xxxiv, 1920, p. 439), who, working with unripe seeds of *Brassica alba* and *Pisum sativum*, have shown that the removal of the testa not only accelerated the germination and terminated the dormant condition of these seeds, but also increased the germination percentage. These authors have suggested that the rest period observed, when attempts are made to germinate immature seeds immediately after removal from the parent plant, may in many cases be attributed to the presence of the testa, there being strong indications that under these conditions the living testa limits the gaseous exchange of the embryo. In this connection it is interesting to note that C. H. Bailey (" Respiration of Shelled Corn," *Univ. Minnesota Exper. Stat. Techn. Bull.*, No. 3, September 1921) remarks (*l.c.*, p. 39) that " during the curing of corn on the cob immediately after harvest the rate of respiration is lower for a time than that of corn of the same moisture content later in the season." Bailey puts forward the view that " possibly a form of dormancy is involved, resulting from a reduced rate of diffusion of oxygen into the respiring cells, or of carbon dioxide therefrom, or both." Moreover, according to H. Sherman (" Respiration of Dormant Seeds," *Bot. Gaz.*, lxxii, 1921, p. 1), the data obtained in the course of a detailed study of dormant seeds of *Cratægus* seem to indicate that the respiratory quotient and the rate of respiration are higher in the case of the after-ripened seed than in the case of the dormant seed.

J. S. McHargue (" Some Points of Interest concerning the Cocklebur and its Seeds," *Ecology*, ii, 1921, p. 110) points out that the dormancy which has hitherto been attributed to the smaller of the pair of seeds borne in the bur of *Xanthium commune* is only apparent, not real. The apparent dormancy of the smaller seed is shown to be due, not to the exclusion of oxygen by the seed coat as was indicated by the earlier investigations of Shull (" Oxygen Pressure and the Germination of *Xanthium* Seeds," *Bot. Gaz.*, xlviii, 1909, p. 387), but to the mechanical conditions within the bur, the chemical composition and cell structure of the two seeds being similar.

W. A. Gardner (" Effect of Light on Germination of Light-sensitive Seeds," *Bot. Gaz.*, lxxi, 1921, p. 249) has carried out an exhaustive series of experiments with the object of determining the fundamental relation of light to the germination processes of seeds. In these experiments the seeds were subjected to a great variety of treatments, chemical, physical, and mechanical; but no general conclusion can be drawn from his results, which, however, demonstrate in a striking way the complexity of the processes involved during the germination of seeds.

The importance of temperature as a factor concerned in the process of germination is emphasised by F. V. Coville (" The Influence of Cold in Stimulating the Growth of Plants," *Smithsonian Report for* 1919, pp. 281–91, Washington, 1921), and by O. Munerati (" L'influenza delle basse temperature sulla germinazione del frumento appena raccolto e dei semi cosi detti freschi," *Atti R. Accad. Lincei, Rendiconti*, 1920, [5], **29**, p. 273). The former states that at ordinary summer temperatures many kinds of seeds will not germinate, but remain dormant until death overtakes them, whereas under the influence of chilling they are stimulated to prompt germination. The case of the Bunchberry, *Cornus canadensis*, is quoted. Seeds of this plant were sown on October 9, 1912, and after the winter chilling germinated promptly in the following spring. A similar lot of seeds sown on the same date, but kept in a greenhouse, the temperature of which was not allowed to fall below 55° F., showed no germinations after twelve months. These seeds were then chilled for two months at a temperature of 35°–40° F., and when brought back into the greenhouse they germinated within a month.

Munerati, working with seeds of *Avena sativa* and *A. fatua*, obtained immediately after harvesting 81 per cent. germinations at a temperature of from 12° to 15° C., as compared with 3 per cent. germinations at 32° to 35° C.

When considering the question of delayed germination and dormancy of seeds the subject of longevity of seeds naturally arises. Loss of vitality may result from a number of causes, such as the degeneration of enzymes, accumulation in the cells as the result of various metabolic processes of substances toxic to seed, exhaustion of food reserves through respiration, etc. etc. Crocker and Groves (" Catalase and Oxidase Content of Seeds in Relation to their Dormancy, Age, Vitality, and Respiration," *Journ. Agric. Res.*, xv, 1918, p. 137) have pointed out that the loss of vitality and death of seeds may probably be due to " a time-temperature denaturing of certain colloids in the embryo," whilst McHargue (" The Significance of the Peroxidase Reaction with Reference to the Vitality of Seeds," *Journ. Amer. Chem. Soc.*, **42**, 1920, p. 612) has concluded that the vitality of seeds depends upon the presence of a substance, presumably an oxygenase, which possesses the property of activating molecular oxygen when exposed to the air, peroxidases being formed as a result of the reaction. When this power is lost the seed is no longer capable of germinating. It is suggested that this peroxidase reaction should be turned to account in seed-testing laboratories for detecting non-viable seed and for distinguishing between seed of high, medium, and low vitality.

On the basis of loss of food reserves due to respiration Sherman (*l.c.*) has calculated the possible life-duration of fully imbibed seeds of a species of *Amaranthus*. The theoretical value, thus calculated, fell far short of the actual value, which certainly exceeds thirty years.

Longevity of air-dry seeds forms the subject of a paper by F. A. Welton (" Longevity of Seeds," *Ohio Agric. Exper. Sta. Monthly Bull.*, vol. vi, Jan.–Feb. 1921, p. 18). Commencing in 1908, samples of seeds of a number of common economic crop-plants were collected each year and stored in corked glass bottles in a room without artificial heat. Early in 1922 the viability of all the samples was tested and the results set out in tabular form. A very high percentage of clover seeds germinated after ten years' storage under the above conditions, whereas some of the grass seeds tested showed no germination after two years' storage. Results of germination tests of a somewhat similar nature are recorded by H. B. Sifton (" Longevity of Seeds of Cereals, Clovers, and Timothy," *Amer. Journ. Bot.*, vii, 1920, p. 223).

A striking example of longevity of seeds in a fully imbibed condition is provided by the recently published results of Dr. Beal's seed viability experiment which was started in the autumn of 1879 (H. T. Darlington, " Dr. W. J. Beal's Seed-Viability Experiments," *Amer. Journ. Bot.*, ix, 1922, p. 266). Twenty lots of fifty freshly gathered seeds from each of twenty-three different kinds of plants were collected with the idea of testing their viability at different times in the future. Each set of seeds was mixed with moderately moist sand taken 3 feet below the surface at a spot where the land had never been ploughed. The mixture of seeds and sand was placed in a pint bottle, the bottle being filled and left uncorked. The bottles were then placed in the soil 20 inches below the surface with the mouth slanting downwards to prevent water accumulating about the seeds. The results now presented are for the germination test which was made in the spring of 1920, *i.e.* in the fortieth year of the experiment. After this long period of dormancy the seeds of ten species germinated, the percentage of germination in the case of a species of *Amaranthus* being as high as 66 per cent.

**ZOOLOGY.** By Reginald James Ludford, Ph.D., B.Sc., University College, London.

*Protozoology.*—The physical structure of the protoplasm of Amœba is discussed by H. Giersberg in a paper entitled, " Untersuchungen zum Plasmabau der Amöben, im Hinblick auf die Wabentheorie " (*Archiv für Entwick. der Organ.*, July 1922). The writer has carried out a series of investigations on chemical influences on the cytoplasm, on pseudopodia formation and amœboid movement, and also experiments with Actinosphærium. The reticulate structure (*wabenstruktur*) of Amœba, he concludes, is only an occasionally appearing physiological condition, and is not the constantly present ground structure of the protoplasm.

R. Weissenberg describes in the *Zool. Anz.*, Bd. lv, No. 3/4, a myxosporidian-like parasite which occurs in the glomeruli of the kidney of the pike. It was present in eight fish out of twenty-six which were obtained from the Berlin markets during the late winter.

*Cytology and Histology.*—The nature of the relationship existing between nuclear and protoplasmic activities is one of the fundamental problems of cytology. It is, therefore, of interest to note a further case of nucleolar extrusions from the nucleus into the cytoplasm, which is described in the oöcyte of the water scorpion by E. A. Spaul (*Jr. R. Micr. Soc.*, Sept. 1922). This process is said to coincide with the deposition of yolk in the oöcyte cytoplasm. The study of the chromosomes in the same insect, during spermatogenesis and oögenesis, has shown that there is a single X-chromosome in the male and a pair in the female, but they are not conspicuous and unable to be identified until cell division takes place.

J. Bronté Gatenby contributes " Some Notes on the Gametogenesis of *Ornithorhynchus paradoxus* " to the *Q.J.M.S.*, vol. lxvi, Part III, 1922. Probably the most interesting fact ascertained by an examination of this primitive mammal, is the presence of a large hollow cavity in the young ovary. " This is undoubtedly a primitive character, which is noticeable even in the adult ovary, in the form of numerous lacunæ throughout the stroma of the ovary." The ovary of the original vertebrate seems to have been a sac-like structure, the stroma being a new formation ; the cells, which in Ornithorhynchus constitute this loose stroma, seem to have been formed by a retro-peritoneal invasion," however they never quite fill the cavity even of the adult ovary.

The discharge of the egg from the ovary differs from that of the placental mammals, being similar to the process occurring in the frog. Yolk-formation resembles that of the bird described by Van Durme.

The cytoplasmic structures in the egg of *Echinarachnius parma* are described by H. Hibbard in the *Jr. of Morphology*, vol. xxxvi, No. 3 ("Cytoplasmic Inclusions in the Egg of *Echinarachnius parma*"). Fat droplets are present in the unfertilised egg, but they disappear during early cleavage stages. The writer suggests that the small spherical mitochondria, which occur scattered throughout the cytoplasm, are formed from fat droplets. Nutritive bodies, containing a fatty component, are also described, and these are believed to be associated in their origin with the mitochondria.

It was found that there was no morphological difference in the cytoplasmic contents of the egg, when fertilised with sperms of the same, or of a different species (Arbacia).

The September number of the *Q.J.M.S.* contains a short paper on "Further Observations on Chromosomes and Sex-determination in *Abraxas grossulariata*" by the late Prof. L. Doncaster, which is edited by Ruth C. Bamber. As the result of staining sections of the eggs of Abraxas during maturation divisions, with various dyes, it is suggested that "there is a certain amount of chromatin left behind, on the equator of the spindle, by the chromosomes when they move apart at anaphase. If this be true, 'it is at least conceivable that the sex-chromosomes, in the eggs of all-female broods, eliminates so much that it becomes functionless as regards sex-determination,' and that here may lie the explanation of the production of all-female families from eggs, some of which contain twenty-seven and others twenty-eight chromosomes."

J. Turchini, in a paper entitled "Étude histologique de la poche du noir des Céphalopodes dibranchiaux" (*Archives d'Anat. Micr.*, Tome xviii, Fasc. 4), describes the histology of the ink-sac, and also the cytological processes involved in the secretion and excretion of the ink. Mitochondria play the fundamentally important part in the formation of the melanin of the ink, while the mucus is elaborated by the ground cytoplasm of the cells of the glandular epithelium.

In the same journal L. M. Betances describes "Les cellules du sang de quelques Lamellibranches." The physiological rôle of these cells is comparable to that of the blood cells of other animals. However, they have not equivalent chemiotactic power for certain chemical reagents. Phagocytosis is limited to certain cells (*les cellules hémohistoblastiques*).

In a paper on "A Critical Study of the Facts of Artificial Fertilisation and Normal Fertilisation (*Q.J.M.S.*, Sept. 1922), J. Gray puts forward evidence in favour of the view that "the activation of an unfertilised egg by a spermatozoon is due to the electro-motive force set up when the two gametes come into contact. The inert egg is activated by the spermatozoon, in the same way as any other resting cell is activated when in intimate contact with an active neighbour. After activation normal development only occurs if two asters are present in the egg."

Other recent papers are :

HERTER, K., "Ein Fall von echter Entwicklungskorrelation aus der Natur bei Rana esculenta L.," *Archiv für Entwick. der Organ.*, July 1922.

MAURER, F., "Säugetierhaare und Tastflecke," *Anat. Anz.*, Bd. 56, No. 3.

PINNEY, E., "The Initial Block to Normal Development in Cross-fertilised Eggs: (i) Crosses with the Egg of Fundulus; (ii) Reciprocal Crosses between Ctenolabrus and Prionotus," *Jr. of Morph.*, vol. xxxvi, No. 3.

PLATE, L., "Über die phylogenetische Entstehung der Milchdrüsen und Haare," *Anat. Anz.*, Bd. 56, No. 3.

TAKAGI, K., "A Cytological Study on the Dog's Thyroid Gland," *Folia Anatomica Japonica*, Sept. 1922.

VERNE, J., "Contribution à l'étude des reins aglomérulaires; l'appariel rénal des Poissons Lophobranches," *Archiv. d'Anat. Micr.*, Tome xviii, Fasc. 4.

*General and Experimental Embryology.*—B. G. Smith has carried out a series of experiments with the eggs of *Cryptobranchus alleghenienisis*, with the view to determining the origin of bilateral symmetry in the embryo ("The Origin of Bilateral Symmetry in the Embryo of *Cryptobranchus alleghenienisis*," *Jr. of Morph.*, vol. xxxvi, No. 3, June 1922). It was found that the action of gravity in the direction perpendicular to the polar axis of the egg during the fertilisation period, was without perceptible effect in determining the direction of the median plane of the embryo. The direction of the entrance of the sperm is not an important factor. Although the first cleavage furrow forms approximately at right angles to the direction of the path of entry of the sperm, yet the direction of the first cleavage bears no fixed relation to the direction of the future median plane of the embryo. In the early blastula stages, the direction of eccentric development of the micromeres bears no constant relation to the direction of the median plane of the embryo. In late stages of the blastula, the bilateral symmetry is manifested by the superficial segmentation pattern and by the internal structure, and this condition is undoubtedly the primary expression of the definitive bilateral symmetry of the embryo.

G. R. de Beer describes "The Segmentation of the Head in *Squalus acanthias*" in the *Q.J.M.S.*, vol. lxvi, Part III, Sept. 1922). He finds that Balfour's interpretation of the somites of the head is correct, and free from the objections which accompany Van Wijhe's. "No gill-slit or arch has been lost in the neighbourhood of the hyoid arch. Nine segments are included in the head of Squalus, of which three are pre-otic (first, second, third), and six post-otic." The fourth breaks down completely into mesenchyme. The fifth forms muscle-fibres but later breaks down. The sixth, seventh, eighth, and ninth produce permanent myotomes. "The tenth somite (first of the trunk, and second post-vagal), corresponds to the first mixed nerve."

The development of the pharyngeal derivatives in the calf (*Bos taurus*) is described by E. L. Anderson in the *Anat. Rec.*, vol. xxiv, No. 1, Aug. 1922. The chief peculiarity in development occurs in the parathyroids. These appear as proliferations of the epithelium of the pouches, adjacent to the corresponding aortic arches, and are highly vascular from the first.

E. Giglio-Tos, in the first of a series of studies in developmental mechanisms, gives a very full account of the processes involved in the early segmentation of the egg of the sea urchin (*Archiv für Entwick. der Organ.*, July 1922). In the same journal A. Lipschütz, B. Ottow, and K. Wagner describe cases of sterility in rabbits resulting from under-development of the testes, the result of removing a part of that organ during development, and at the same time cutting through the ductus epididymis.

*Invertebrate Morphology.*—A paper "On the Septal and Pharyngeal Glands of the Microdrili (Oligochæta)" is contributed by J. Stephenson to the *Trans. R.S. Ed.*, vol. liii, Part I, No. 12. He points out that the chromophil cells in the Microdrili, as in the earthworms, have no direct connection by means of long-drawn-out necks with the alimentary epithelium. They therefore constitute "ductless glands," and their secretion (largely disintegration products) is an "internal secretion, which, in most cases, mixes with the cœlomic fluid."

The condition of the septal glands of Enchytræids is comparable with that in earthworms. The secretion in both cases reaches the pharyngeal lumen by percolation, in the former down strands of non-staining tissue, and in the latter through the felt of muscular fibres.

The chromophil cells are believed to arise from the peritoneal lining of the cœlomic cavity, and are therefore mesoblastic in origin.

In a paper on "The Infra-cerebral Organs of Peripatus" (*Q.J.M.S.*, vol. lxvi, Part III, Sept. 1922), W. J. Dakin suggests that the infra-cerebral vesicles of this animal are homologous with the cephalic pits of other Tracheate embryos. In the latter the pits become closed off, the walls become parts of the cerebral ganglion, and the cavities disappear altogether. In Peripatus, on the other hand, the vesicles remain, but they are gradually constricted off from the rest of the supraœsophageal ganglion. The adult condition in Peripatus is, then, an embryonic stage in the Myriapoda.

Other important papers are :

Evans, T. J., "Calma Glaucoides: A Study in Adaptation," *Q.J.M.S.*, vol. lxvi, Part III, Sept. 1922.

Hilton, W. A., "The Nervous System of Phoronida," *Jr. of Comp. Neur.*, vol. xxxiv, No. 4, Aug. 1922.

Seidler, H. J., "Beiträge zur Kenntis der Polynoiden, 11," *Zool. Anz.*, Bd. lv, Nos. 3, 4.

*Experimental Zoology of Planarians.*—"The Control of Head-formation in Planaria by Means of Anæsthetics" is the subject of an investigation by J. W. Buchanan (*Jr. of Expt. Zool.*, vol. xxxvi, No. 1, July 1922). Experiments conducted with headless pieces of Planaria showed that the factors controlling head-formation are non-specific, and strongly support Child's conclusion, *i.e.* that head-formation is determined chiefly by the relative activities of two antagonistic factors, *viz.* :

"(1) The tendency of the cells near the anterior cut surface of the piece to de-differentiate and develop into the head of the new individual ; and (2) the tendency of the whole piece, exclusive of the cells directly concerned in the development of the new head, to maintain the differentiation of the old individual. This region exerts a certain degree of control over the cells near the anterior cut surface and consequently tends to prevent the development of the new head."

Anæsthetics can interfere with these processes by inhibiting the activities of the cells of the anterior cut surface, and thus decreasing head frequency, and by inhibiting the increase of the metabolic activity of the whole of the cut portion ; this effect may overbalance the direct effect of section on the anterior cells and thus increase head frequency. The ultimate result depends upon the concentration of the anæsthetic, and the length of period of its action. The anæsthetics employed in these experiments were chloretone, chloroform, chloral hydrate, ether, and ethyl alcohol.

J. M. D. Olmsted contributes two papers dealing with experimental work on Polyclads to the same number of the *Jr. of Expt. Zool.* In "The Rôle of the Nervous System in the Regeneration of Polyclad Turbellaria," he describes experiments with *Planocera californica*, *Phylloplana littoricola*, and *Leptoplana saxicola* which show that these species follow the general rule of polyclad regeneration. They are able to restore missing parts, provided the cephalic ganglia are intact, but if these organs are injured, new nervous tissue is not added to restore the brain to its original size, and if they are entirely removed, regeneration cannot take place anteriorly, though it may do so posteriorly.

In describing the mode of locomotion of these same Polyclads in a second paper, " The Rôle of the Nervous System in the Locomotion of Certain Marine Polyclads," Olmsted points out that locomotion is essentially the same in these organisms as in the Molluscs. This is, therefore, another instance of evolution along the same lines in two quite different groups.

A further paper dealing with experimental work on Planarians, " Regeneration und Transplantation, 11 Teil," appears in the *Archiv für Entwick. der Organ.*, July 1922.

*Vertebrate Morphology.*—In a paper " On the Endocranial Anatomy of some Oligocene and Pleistocene Mammals " (*Jr. of Comp. Neur.*, vol. xxxiv, No. 4, Aug. 1922), R. L. Moodie has described a number of endocranial casts of mammals from the White River Beds of South Dakota which range from Lower to Middle Oligocene, and two brain cases from the Pleistocene deposits of the Rancho la Brea of Southern California. From the types studied the writer concludes that there has been no cerebral development in the rodents since Oligocene times, while the Insectivora, as indicated by Ictops, have retrograded in cerebral structure. Both the æluroid and cynoid carnivores studied indicated clear cases of cerebral evolution since Oligocene times.

Other papers of special interest are the following :

Dawson, A. B., " The Cloaca and Cloacal Glands of the Male Necturus," *Jr. of Morph.*, vol. xxxvi, No. 3, June 1922.

Hay, O. P., " On the Phylogeny of the Shell of the Testudinata and the Relationships of Dermochelys," *Jr. of Morph.*, vol. xxxvi, No. 3, June 1922.

Krieg, H., " Streifung und Stromung," *Archiv für Entwick. der Organ.*, July 1922.

*General Experimental Zoology.*—A great deal of work has been done in this country and abroad on the transplantable tumours of mice, so that special interest attaches to a paper on " A Genetic Analysis of the Factors underlying Susceptibility to Transplantable Tumours," by L. C. Strong (*Jr. of Expt. Zool.*, vol. xxxvi, No. 1, July 1922), in which is described the result of transplanting tumours into genetically homogeneous races of mice. The tumours used in this research were two adenocarcinomata of the mammary gland, which had arisen spontaneously. In general, no rhythms of tumour growth were found to take place, but sudden fluctuations in growth activity might sporadically occur, which it is suggested might be due to a process analogous to mutation.

Race was found to be the primary factor which determined whether or not a given individual did or did not grow the tumour progressively. " Susceptibility and non-susceptibility are manifestations of the genetic constitution of the individual."

Factors of secondary importance are age and sex. Removal of the gonads produced, in the stock employed, a significant increase in percentage reactions, in mice attaining sexual maturity.

Another paper of importance to experimental zoologists is " Extremitätentransplantationen an Anuren " in the *Archiv für Entwick. der Organ.*, July 1922.

*Zoological Technique.*—Owing to the considerable increase in our knowledge of the physical condition of protoplasm that has resulted from micro-dissection work, special interest is attached to a paper by R. Chambers on " New Apparatus and Methods for the Dissection and Injection of Living Cells " (*Anat. Rec.*, vol. xxiv, No. 1, Aug. 1922). The basic principle of the instrument described consists in rigid bars, attached to the stage of the microscope, which are screwed apart against springs. " The movements performed by this instrument are so accurately controlled that one can readily carry out such delicate operations as puncturing mammalian blood corpuscles, tearing off the sarcolemma of a muscle fibre, drawing out nuclear chromatin strands and even cutting up the chromosomes of insect germ cells." With the micropipette one can either inject substances into, or withdraw material from, a cell.

In a " Note on the Comparative Effects on Tissues of Isotonic Saline and Distilled Water when used as Solvents for Mercuric Chloride and Formol in Histological Fixation " (*Q.J.M.S.*, Sept. 1922), H. M. Carleton points out that " while it is immaterial whether a concentrated (6 per cent.) solution of mercuric chloride be dissolved in isotonic saline or distilled water, formol of 5 per cent. should be made up in isotonic saline and not in distilled water."

Other papers include :

Brooker, A., " The Plunger Pipette—a New Instrument for Isolating Minute Organisms," *J.R.M.S.*, Sept. 1922.

Hartmann, C., and Heuser, H., " A Black Background for Photographing Objects in a Liquid Medium," *Anat. Rec.*, vol. xxiv, No. 1.

**ANTHROPOLOGY.** By A. G. Thacker, A.R.C.S., Zoological Laboratory, Cambridge.

An issue of first-class importance to anthropologists has been raised during the last twelve months by the publication of the discovery of a tooth in the Pliocene of Nebraska, which is believed by many to be that of a primitive anthropoid Primate. The view that the tooth belonged to an early member of the Hominidæ or Simiidæ has the support of Prof. H. Fairfield Osborn and other leading American palæontologists, and Prof. Osborn contributed an article on the subject, with illustrations, to *Nature*, August 26, 1922. There have been other articles on the subject in *The Times* and elsewhere, and these, though mainly popular in character, have served to elicit the fact that some British anatomists, including Elliot Smith, are inclined to accept Osborn's conclusions, whilst others, including Smith Woodward, are sceptical. If the tooth be really in any sense humanoid, the conclusions to be drawn are certainly far-reaching; and the reader may be reminded of the present state of knowledge on these matters. The Anthropoidea (higher Primates) are divisible into two sharply defined groups, the Platyrrhina, living in the Western Hemisphere, and the Catarrhina, living in the Eastern Hemisphere. The Catarrhina include not only all species of men and great apes, but also all the familiar monkeys of Asia and Africa. Now there is not the slightest trace of fossil Platyrrhina in the Eastern Hemisphere. And, similarly, there has hitherto been no serious evidence that any Catarrhine lived in the Western Hemisphere before that very recent date when Mongoloid savages—ancestors of the American Indians—first made their way across what was then the Isthmus of Behring. The case has therefore appeared to be one in which negative geological evidence really does have some weight. And referring to this new discovery Prof. Osborn says: "This is the very first evidence, after seventy-five years of continuous search in all parts of our great western territory, of a Primate of any kind above the ranks of the numerous lemur-like and tarsier-like lower Primates which have long been known in our Eocene beds." On the other hand, a considerable number of Southern Asiatic mammals passed into western America in early Pliocene times, and the existence of free land communication is certain; the difficulty has been rather the improbability of a continuous forest-belt, suitable for apes, passing as far north as the Behring isthmus. Osborn believes that the tooth is a second upper molar. It was discovered by a geologist named Harold J. Cook in 1921 in the so-called Snake Creek beds of Western Nebraska, and Osborn has made it the type of a new genus and new species, upon which he has bestowed the unwieldly name *Hesperopithecus haroldcookii*. (It may be remarked in passing that it was surely unnecessary to drag in the discoverer's first name.) Osborn will not give any opinion as to whether *Hesperopithecus* "is a member of the Simiidæ or of the Hominidæ." It is, he says, "a new and independent type of Primate, and we must seek more material before we can determine its relationships." The tooth is described in detail, and excellent illustrations are given, with the object of comparing it with the corresponding tooth in *Pithecanthropus*, in the chimpanzee, and in the American Indian. Another tooth, said to be a third upper molar of an old individual, and discovered as long ago as 1908, is now referred by the American palæontologists to *Hesperopithecus*. This evidence of the presence of a great Catarrhine in North America in the Pliocene is, however, very slender, and it is probably desirable at present to preserve an agnostic attitude on the question.

The *Proceedings of the Prehistoric Society of East Anglia*, vol. iii, pt. 3 (1920–21), contain, as usual, a number of most interesting articles. Attention may be drawn to an article by Reid Moir entitled: "Further Discoveries of Humanly Fashioned Flints in and beneath the Red Crag of Suffolk." During the last three or four years, Reid Moir has been linking up the Rostro-Carinate implements of the Pliocene, the artefact nature of which he was the first to prove, with the earliest Chellian implements ; and it may now be said that the gap—once very wide—between these two "industries" has been satisfactorily bridged. The *Proceedings* also contain reports by Prof. Marr and others on certain excavations at Mildenhall, which were undertaken in 1920. The Presidential Address by the Rev. H. G. O. Kendall was entitled : "Eoliths : Their Origin and Age." This contribution is insufficiently critical, and the author does not really get to grips with the required proofs of these alleged implements.

The following papers may also be noted :

In the *American Journal of Physical Anthropology*, vol. iv, No. 2 (April to June 1921) : "The Types of Scapulæ," by W. W. Graves ; "Further Studies in Tooth Morphology," by A. Hrdlicka ; and "Hereditary and Racial Variation in Palmaris longus," by J. W. Thompson, J. McBatts, and C. H. Danforth. And in the same *Journal*, vol. iv, No. 3 (July to September 1921) : "The Testing of Physical Efficiency," by M. Jindrich ; and "The Quantitative Determination of Black Pigmentation in the Skin of the American Negro," by T. Wingate Todd and Leona van Gorder. And in the *Proc. Prehist. Soc. E. Ang.*, vol. iii, pt. 3 (1920–21) : "The Grimes Graves' Fauna," by W. G. Clarke ; and "The Congress at Liège" (of the International Institute of Anthropology), by M. C. Burkitt.

# ARTICLES

## THE ANALYSIS OF CRYSTAL-STRUCTURE BY X-RAYS

By W. T. ASTBURY, B.A.
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It is now just over ten years since Laue first proposed the use of crystalline structures for the investigation of the real nature of X-rays. From Laue's hypothesis and the experiments of Friedrich and Knipping which confirmed it have arisen two parallel lines of research, one of which still uses known crystal-structures for the investigation of X-rays, while the other uses well-defined X-rays as a means of arriving at the ultimate significance of crystal-structure. The work of the Braggs and their followers has, of late, been largely directed along the second of these two main lines of research, and, if we ignore the blank left by the war, it has been so fruitful of results that it is now felt that we are rapidly passing into a stage of development of the subject when principles will be evolved that will not only correlate the facts of crystal-structure, but also, at the same time, throw considerable light on the hidden forces of the atom itself. When the science was new, crystal-structure was studied for its own sake, but since then the outlook has broadened considerably, and the elucidation of its problems for the sake of physics and chemistry and science in general is a subject that is growing apace.

Probably the most important recent advance in the study of crystal-structure has been the work of Sir W. H. Bragg on the structure of organic crystals (*Proc. Phys. Soc.*, vol. xxxiv, December 1921). Apart from the purely physical and crystallographic point of view, this work possesses a peculiar interest for the chemist, insomuch as it emphasises and confirms the structural formulæ to which he has so long and confidently pinned his faith. Hitherto the structural formulæ of the organic chemist have been merely the theoretical links in the powerful chain which stretches from marsh-gas at one extreme to the most complicated dyes at the other. But now the searching analysis of crystals provided by the use of X-rays has shown that, far from being just "paper" things, certain formulæ well known in organic chemistry are founded on actual stable physical structures.

Bragg starts out with the hypothesis that the benzene and naphthalene rings are actual systems, having each a definite size and form, which are built as a whole into the organic substances in which they occur. Indeed, without some such simplifying hypothesis, the complicated molecules of organic chemistry might well present almost insuperable difficulties. However, Bragg proceeds to give good *a priori* reasons for such a supposition. The diamond is a very rigid cubic structure

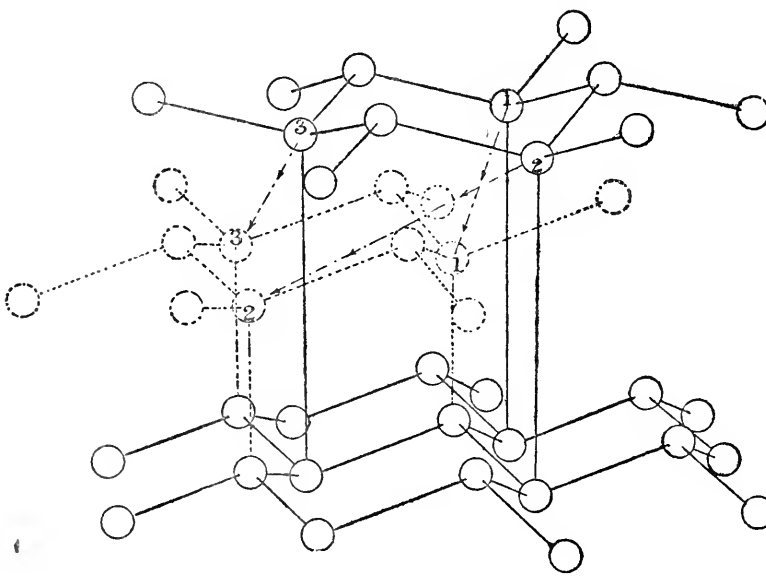


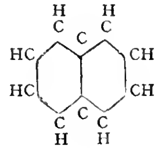

FIG. 1.

The fine lines of the diagram show the structure of the graphite. By moving the top layer to the position shown by the broken lines the diamond structure is obtained.

*(By permission of the Physical Society of London.)*

in which all the carbon atoms are tied together in such a way that each is at the centre of gravity of four others (*Proc. Roy. Soc.*, A, vol. lxxxix, p. 277). Its rigidity and open structure imply that great force is needed to alter the orientation of any coupling with respect to the other three belonging to the same atom (*Proc. Phys. Soc.*, vol. xxxiii, August 1921). Viewed as a whole, the structure appeared as a series of puckered layers parallel to the perfect cleavage planes which lie perpendicular to the four triad axes which emerge from the corners of the cube. From this structure that of graphite can be obtained very simply by a certain shift applied to one of two such parallel layers (Fig. 1). [In this point, Bragg accepts Hull's determination of the structure of graphite (*Phys. Rev.*, vol. x, p. 692, 1917) in preference to that of Debye (*Physik. Zeitsch.*, vol. xiii, p. 297, 1917), which maintains that the layers of atoms are not puckered but flat. In any case, in the light of more recent considerations, it is probable that neither analysis is complete, though almost undoubtedly Hull's is nearer the truth.] Whereas in diamond all the atoms were equidistant, ($1 \cdot 54 \times 10^{-8}$ cm. between centres), we have now in graphite layers of even more rigidly connected atoms ($1 \cdot 50 \times 10^{-8}$ cm. between centres), each layer being loosely connected to the next across the still more perfect cleavage by bonds of length $3 \cdot 25 \times 10^{-8}$ cm. Now these stable puckered layers consist of distorted hexagons of carbon atoms, alternately directed upwards and downwards. Fig. 1 shows them clearly. They are perpendicular to the hexagonal axis of graphite crystals, and it is parallel to them that the crystals cleave so readily into shiny black flakes. The distorted but stable hexagons of carbon atoms which constitute these flakes are conceived by Bragg to be the physical basis of the well-known benzene ring. Benzene is derived from one such hexagon, naphthalene from two adjacent ones, anthracene from three, and so on. From Hull's measurements we have now a means of calculating with sufficient approximation the actual shape and dimensions of these various rings.

Naphthalene, $C_{10}H_8$,




was chosen first for experimental investigation for the reason that it forms well-defined crystals solid at ordinary temperatures. But in the case of benzene, though it would seem more natural and desirable to tackle its structure first, we are at once confronted with the difficulties of producing and working at low temperatures with crystals about which very few reliable crystallographic facts are known. At present, not even an accurate estimate of so fundamental a quantity as its specific gravity is available. With regard to naphthalene, X-ray observation, assisted by the data given in vol. v of Groth's *Chemische Krystallographie*, shows at once that in its ultimate monoclinic space-lattice ($\beta = 122° \ 49'$)

$$a = 8 \cdot 34 \times 10^{-8} \text{ cm.} \qquad b = 6 \cdot 05 \times 10^{-8} \text{ cm.}$$
$$c = 8 \cdot 69 \times 10^{-8} \text{ cm.},$$

and that there are two molecules to each cell. A unit monoclinic cell is shown in Fig. 2 (*a*). Ignoring for the moment the points P and Q, the fundamental parallelepiped is OBFACDEG, possessing, if OBFACDEG are points or spheres, the full symmetry of the monoclinic system, a plane of symmetry parallel to the plane OCGA, and a dyad axis of symmetry perpendicular to the plane OCGA. OA, OB, OC are the three axes of reference, $OA = a$, $OB = b$, $OC = c$, while the angle $\beta = AOC$. The angle $AOB = 90°$. Fig. 2 (*a*) represents a unit cell of naphthalene, and Fig. 2 (*b*) of anthracene.

If now we assume that there is one molecule lying at each

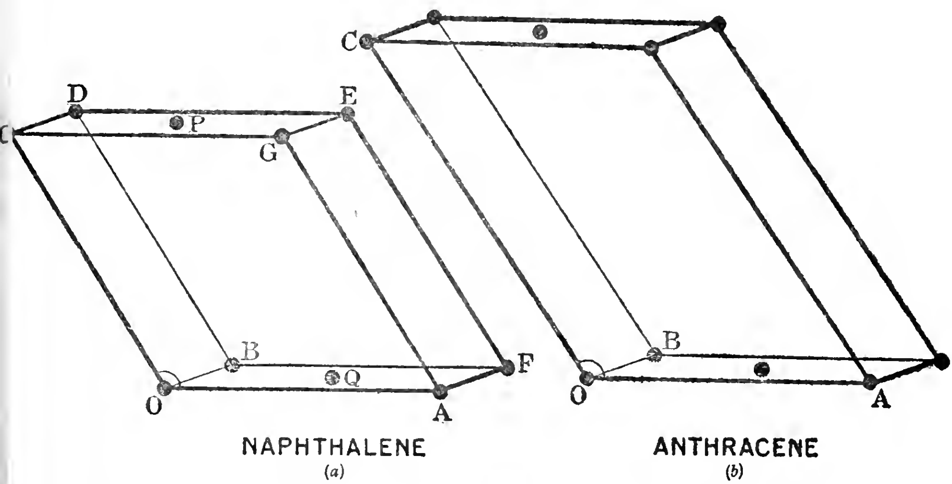



FIG. 2.—Unit cells of naphthalene and anthracene drawn to the same scale.

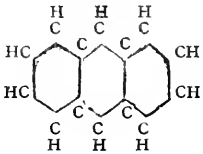
| | $OA = a$ | $OB = b$ | $OC = c$ |
|---|---|---|---|
| Naphthalene | 8·34 | 6·05 | 8·69 |
| Anthracene | 8·7 | 6·1 | 11·6 |

Naphthalene $x = BOC = 90°$, $\beta = COA = 122° 49'$, $\gamma = AOB = 90°$.
Anthracene $x = BOC = 90°$, $\beta = COA = 124° 24'$, $\gamma = AOB = 90°$.

(*By permission of the Physical Society of London.*)

corner of the fundamental cell, and no others whatsoever within the cell, we can easily calculate what the spacings of all the crystal planes should be. But further X-ray examination reveals that the spacings of both the planes parallel to OCDB and those parallel to OCGA are actually half the calculated spacings. These facts lead inevitably to the conclusion that there are two other molecules in the cell and lying somewhere along the line joining the centres of the faces CDEG and OBFA. Bragg places these two molecules actually in these two faces themselves. They are represented in the figure by the points P and Q.

The next salient fact is that in anthracene crystals, $C_{14}H_{10}$,

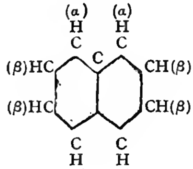



we find that

$a = 8{\cdot}7$ A.U. $\qquad b = 6{\cdot}1$ A.U.
$c = 11{\cdot}6$ A.U. $\qquad \beta = 124^\circ\ 24'$
[1 Ångström Unit (A.U.) = $10^{-8}$ cm.]

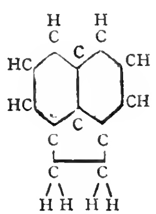
and that there are again two molecules per cell. We notice that $a$, $b$, and $\beta$ are practically unaltered, whereas $c$ is lengthened by 2·9 A.U.; *i.e.*, if we assume that the molecules in both crystals lie end to end along the $c$-axis in structures that are similar, an extra ring of the benzene dimensions (2·5 A.U.) would account for most of the increase in length of the $c$-axis. Moreover, considering that the overall lengths of the two molecules, without allowance for the hydrogen atoms at their ends, are 6·41 A.U. and 8·86 A.U. respectively, we have now a vacant space between the ends of two molecules of rather more than 2 A.U. in which two hydrogen atoms have to be fitted; which agrees very well with what might be expected, even though we have no definite knowledge of the actual distance between the centres of a carbon and a hydrogen when united by a valency bond, nor between two hydrogens when not so united.

It is difficult, without the aid of such excellent models as Bragg himself uses, to impart or conceive a clear mental picture of the completed structure which he has ascribed to the naphthalene cell. Suffice it here to say that in the final arrangement all the molecules (which may be represented sufficiently for our purpose by the chemical structural formula)




lie practically in planes parallel to OCGA (the symmetry plane of the cell). The $\beta$-hydrogens of each molecule lie up against the corresponding hydrogen of the next, while the $\alpha$-hydrogens abut against the carbon atoms of the next molecule. The perfect cleavage of the crystals is parallel to the plane CDEG, and this is sharply marked in the model as passing across the junctions of the $\beta$-hydrogens. This point will be readily visualised when we remember that the molecules lie lengthwise parallel to OC in planes parallel to OCGA. The way in which the crystalline structure reveals the perfect cleavage plane is significant in that it indicates that across the junctions between molecule and molecule, in spite of the fact that it is undoubtedly the forces across these junctions that bind the molecules into the crystal, there are forces far weaker than those valency bonds which unite the atoms of the same molecule. In this statement, we have the essence of the great difference so far observed between the organic and those inorganic structures, such as the alkali halides, with which Bragg's work has made us so familiar. In the latter the identity of each molecule seems to be lost, in fact they may be called "ionic" structures, but in the former we experience little difficulty in picking out complete individual molecules.

The next step in this work on organic crystals was the investigation of a molecule into which some complexity has been introduced by a substituted group. Bragg considers first the case of acenaphthene, $C_{12}H_{10}$,



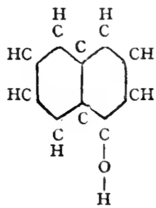
Here the molecules have been made one-sided by the substitution of a group of two carbons and four hydrogens for the two hydrogens on one side. The structure through this change becomes rhombic bipyramidal with four molecules to the unit cell and

$$a = 8{\cdot}32 \text{ A.U.} \qquad b = 14{\cdot}15 \text{ A.U.} \qquad c = 7{\cdot}26 \text{ A.U.}$$

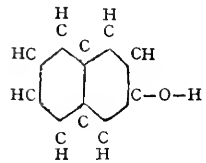
The rhombic bipyramidal cell is like those shown in Fig. 2, if $\beta$ is made equal to a right angle; that is, it is simply a parallelepiped all the angles of which are right angles. It possesses the following elements of symmetry: three planes of symmetry parallel to the faces of the simple parallelepiped, and three dyad axes of symmetry which are parallel to the intersections of the three planes of symmetry (and therefore parallel to the three rectangular crystallographic axes *a*, *b*, and *c*).

The molecules now lie one at each corner of the cell and one at the centre of each of the faces of the cell. But whereas the molecules at the corners of the cell and at the centres of the faces CDEG and OBFA (Fig. 2 [*a*]) are oriented parallel to the plane BDGA, those at the centres of the faces OCDB, AGEF, OCGA and BDEF all lie parallel to the plane OCEF, an arrangement which was necessitated by the observation that the spacing between the planes parallel to BDGA is actually twice the value that would be calculated on the assumption that all the molecules are parallel. A model shows at once that again the cleavage plane passes through the junctions of the β-hydrogens, while the substitution group on the side of the molecule seems to engage with a neighbouring molecule on its unsubstituted side. Two facts with respect to the structure are left doubtful. They are (1) that the molecule of acenaphthene seems to be rather shorter than the naphthalene molecule, and (2) that there is an indication that alternate planes parallel to ACDF differ somewhat.

Bragg next considers the two naphthols :



α-naphthol.



β-naphthol.

Of these α-naphthol gives

$$a = 13{\cdot}1 \text{ A.U.} \qquad b = 4{\cdot}9 \text{ A.U.} \qquad c = 13{\cdot}4 \text{ A.U.}$$

with four molecules to the unit cell (again monoclinic prismatic, Fig. 2). These four molecules are distributed thus : one at each corner of the cell, one at the centre of each of the faces OCGA and BDEF, and one at the middle of each of the edges of the cell. However, alternate planes parallel to OBFA are quite different ; in fact, the combined data from crystal and powder reflections are sufficient to show that there are really four different orientations of the same molecule. When a model is made, it appears that once more these lop-sided molecules lie criss-cross with the cleavage plane passing markedly through the β-junctions. The hydroxyl groups fit into their places very naturally, rather close together, in pairs. There seems to be a special attraction between two oxygens exerted across every alternate plane parallel to OBFA. The other planes parallel to OBFA are cleavage planes.

For β-naphthol very few data beyond the spacings

$$a = 5{\cdot}85 \text{ A.U.} \qquad b = 4{\cdot}28 \text{ A.U.} \qquad c = 8{\cdot}7 \text{ A.U.}$$

have been obtained. Nevertheless, it seems likely that the structure is really the same as that of $\alpha$-naphthol, with four different orientations of molecules, lying mainly along the *c*-axis, and the cleavage plane still cutting across the $\beta$-junctions.

Experimental work has been done and is being continued on compounds, such as benzoic and phthalic acids, which contain the single benzene ring only. The analysis of these, however, is not yet complete. As mentioned above, benzene itself presents exceptional difficulties, and this unfortunate circumstance has materially retarded the investigation of the single-ring compounds. Still, the work to date has shown that valuable information respecting the linear dimensions of organic crystals is to be gained by the methods of X-ray analysis, and also has hinted at the existence of a certain general principle, *viz.*, that the benzene and naphthalene rings and, in all probability, other ring combinations known to organic chemists have in crystals actual form and dimensions which are nearly, if not quite, the same when they are built into different compounds. And moreover, as Bragg points out, the work agrees extremely well with that of Langmuir on surface films and the results of Adam (*Proc. Roy. Soc.*, vol. xcix, July 1921) and several other workers. The forces that link atoms are certainly of more than one kind. Besides the strong valency bonds, there are undoubtedly bonds of a much weaker character, and it is such bonds as these that unite the molecules of organic compounds and lead to the beautiful architecture of their crystal formation.

It has been a great improvement to the powder method of crystal analysis that recently X-ray tubes have been devised which offer, as their main characteristic, special facilities for bringing the powder and photographic plate close up to the anticathode. At such short distances as are now used, the beam of rays is so intense that powder reflections can be easily examined by the ionisation spectrometer (see below), and, in fact, reflections from good large crystals can even sometimes be detected by a fluorescent screen. Several workers have employed apparatus of similar design. The Swedish physicist, Siegbahn, uses such a tube at Lund for his precision measurements of the high-frequency spectra of the elements (*Phil. Mag.*, June 1919), and an interesting tube of this type is the one described by A. Müller (*Phil. Mag.*, September 1921). This latter was designed in order to obtain measurements of the L-spectrum from a liquid mercury anticathode. The tube is largely of the home-made variety, its body being a bottle with the bottom cut off. The electrodes and joints are water-cooled, since the joints are made gas-tight merely by the use of sealing-wax. There is no filament in the cathode, the requisite degree of exhaustion being attained by means of a Gaede pump. The great advantage of a tube of this kind, besides the one mentioned above, is the ease with which it can be taken to pieces and put together again. The use of sealing-wax joints allows one to overhaul or substitute other metals for anticathode in a very short time.

The tube used in Sir William Bragg's laboratory at University College, London, was designed by Mr. G. Shearer, working for the Department of Scientific and Industrial Research (*Electrical Review*, vol. xc, June 1922, p. 909).

Its body is a glass tube about 20 cm. long and 5 cm. diameter (R, Fig. 3). It is not a gas-tube like Müller's, but uses a tungsten filament, the rays from which are focused by aid of a long brass tube, S, extending practically the whole length of the body, on to a water-cooled anticathode. The joints are of sealing-wax and, with the electrodes, are water-cooled also. The rays emerge from two diametrically opposite windows, W, of aluminium leaf placed at right angles to the anticathode, so that two photographs can be taken simultaneously. The system is evacuated by a Gaede pump or a pair of Volmer diffusion pumps aided by a weaker subsidiary pump. Under working conditions, the distance from filament to anticathode is from 2½ to 4 cm., from anticathode to powder about 2 cm., and from powder to plate 2 to 4 cm. The crystal powder is either mounted on a piece of paper or contained in a glass capillary tube. In the latter case it can be readily rotated while the photograph is being taken, thus ensuring greater intensity and definition for the lines. Mr. Shearer's tube is generally run at about 30,000 volts, and an exposure of about 6 to 10 milliampère-hours is sufficient to obtain good photographs, especially in the case of organic crystals where the atoms are light. Drawings of naphthalene and phthalic acid are shown in Fig. 4.

The X-ray tube described above can be very effectively used in combination with the ionisation-spectrometer, for Sir William Bragg (*Proc. Phys. Soc.*, vol. xxxiii, June 1921) has now shown that finely powdered crystals can be examined by the ionisation method after the manner of examining a single perfect crystal. The powder is pasted on to a flat surface and placed on the table of the spectrometer in the position ordinarily occupied by the face of a single crystal. With a bulb current of 1 milliampère and slits wide enough to take in a reflection over half a degree, the whole spectrum can be run through very rapidly and, if the tube is steady, the relative intensities of the various orders of reflection examined in detail. Spectra of copper, naphthalene, $\alpha$-naphthol, and benzoic

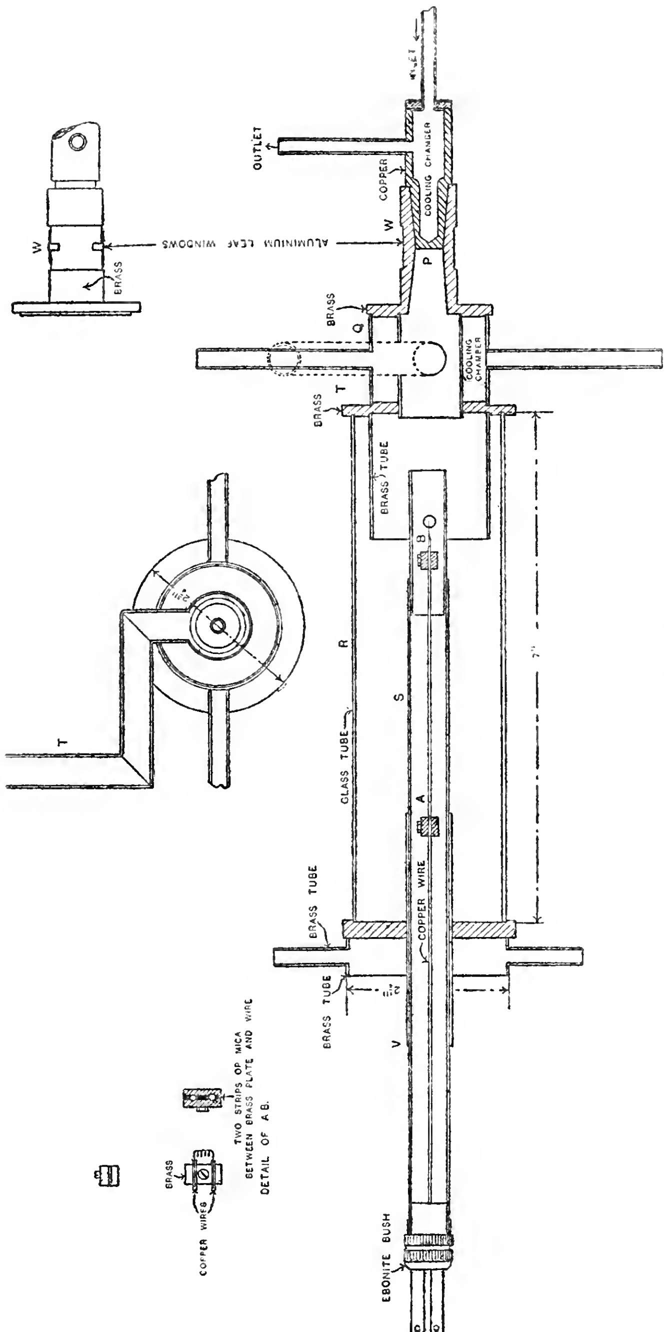



FIG. 3.—A new X-ray tube.
*(By permission of the "Electrical Review.")*

acid obtained by Mr. Shearer for Sir William Bragg are given in the latter's paper on organic crystals.

The study of inorganic crystals is bringing home to us every day that there are a few underlying principles which, if thoroughly understood and properly applied, may in time enable us to arrive at the nature of any crystal-structure, if not by theoretical reasoning alone, at least by theory assisted by a maximum of one or two X-ray observations. Such a principle is that mentioned by Sir W. H. Bragg in his paper on the crystal-structure of ice (*Proc. Phys. Soc.*, vol. xxxiv, April 1922). In brief, this "polar principle," as it may be called, states that in that class of crystals in which the molecules are broken into simple positive and negative ions, the structural arrangement is such that each positive surrounds itself with negatives, and each negative by positives. The relative

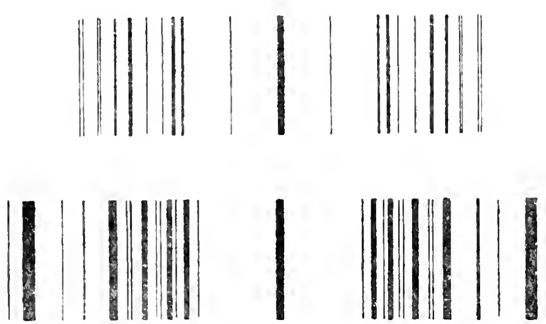


Fig. 4.—X-ray drawings: naphthalene (top) and phthalic acid (bottom).

numbers of the ions of each kind are governed by valency considerations. In these crystals the individuality of each molecule *seems* to disappear; in fact, we have the old phenomenon of ionic dissociation in a new form, not, as in solutions, just a haphazard arrangement, statistically neutral, but an orderly arrangement of ions defined by certain fundamental laws of symmetry and valency. For instance, in sodium chloride, each positive ion is surrounded by six negative ions and each negative ion by the same number of positive ions. In fluorspar, each calcium atom, or rather ion, is surrounded by eight fluorines, and each fluorine by half that number of calciums. In the same way, though the process becomes more difficult to work out, the principle can be extended to elements of higher valency, and still holds good in such cases as magnetite and ruby. In the light of our maturer knowledge of these things, it is well conceivable that the complete structure of the alkali halides might have been deduced from this principle and a knowledge of their specific gravities without making a single X-ray observation.

Bragg has applied these arguments to the elucidation of the crystal-structure of ice. Quite independently of X-ray analysis, he arrives at an arrangement which agrees admirably with experimental results obtained previously by other workers. The reasoning is so beautiful that it is well worth giving in some detail. The hypothesis is that each positive ion is surrounded symmetrically by negative ions and vice versa; and, in view of the low density of ice, let the number of neighbours be in each case as small as possible. The crystal is to be hexagonal and have the right density.

A simple calculation shows that the structure must be such that each ion of one sign is closer to its neighbours of the other sign than the fluorspar arrangement allows, and the low density of ice suggests that the most economical arrangement should be tried. Now there are two arrangements of like atoms in which each atom is at the centre of gravity of its four neighbours. One is exemplified by diamond, and in this the number of atoms could not be fewer, and the other is a hexagonal arrangement obtained from the other by parallel shifts of the tetrahedral planes, without finally altering the value of the universal distance between two neighbours. Zinc oxide is a case of this latter structure. Replace now each carbon atom of the hexagonal structure by oxygen and insert a hydrogen between each pair of oxygens. Each oxygen is now surrounded by four hydrogens and each hydrogen by two oxygens; and, moreover, the number of neighbours has been reduced to a minimum.

The dimensions of this structure can be obtained directly by comparison with diamond. Each point of the lattice now represents a molecular weight of 18 instead of 12, and yet the specific gravity has been lowered from 3·52 to 0·9165. Hence, if the linear dimensions are increased in the ratio $1:p$, we have

$$p^3 = \frac{18 \times 3{\cdot}52}{12 \times 0{\cdot}9165} \therefore p = 1{\cdot}79.$$

The distance between the centres of two carbon atoms in diamond is 1·54 A.U. Hence the distance between the centres of two oxygen atoms in ice is $1{\cdot}54 \times 1{\cdot}79 = 2{\cdot}76$ A.U. The distance between two consecutive basal planes will be now 3·67 A.U., and the distance between two atoms in the same plane 4·52 A.U. These figures agree exactly with the observations of Dennison (*Science*, September 24, 1920; *Phys. Rev.*, June 1921). As would be expected, the structure is extremely empty. The hydrogen has apparently a larger diameter than that of oxygen, if we give to oxygen the value of 1·30 ; but, if the arrangement is correct, we can truthfully say only that the sum of the diameter of oxygen and hydrogen is 2·76 A.U.

The recently published work (Iron and Steel Institute, Annual Meeting, May 1922) of Dr. Arne Westgren and Gösta Phragmén, of Stockholm, has considerably cleared the air with regard to the crystalline structures of the various forms of iron and steel. One of these authors presented a report last year (*Journal of the Iron and Steel Institute*, 1921, No. 1, p. 303), but their later paper announces great improvements in their methods and results. They have used the powder method of analysis, the X-rays being produced by a tube of the Siegbahn type, the metallic body of which was constructed of S.K.F. ball-bearing steel. The characteristic rays from an anticathode of iron passed out of five windows simultaneously, while the tube was evacuated by means of a combination of a mercury vapour jet pump and a mercury diffusion pump of the Volmer type. The final arrangement was such that the tube ran very steadily at 45,000 to 50,000 volts and 10 to 12 milliampères. The reconstructed camera enabled the authors to allow the glowing iron wire to rotate and thus to obtain photographs clear enough for reproduction. The iron wire in the camera was heated by an alternating current of low voltage and the temperature was determined by use of an optical pyrometer.

In the case of the iron modifications, photographs were taken at ordinary temperature and at about 800° C., 1,100° C., and 1,425° C. The time of exposure was $2\frac{1}{2}$ hours. The very interesting result is obtained that, allowing for the slight displacement of the lines due to heat expansion, the photographs of $\alpha$- and $\beta$-iron are of the same type, while the $\gamma$-iron photograph is of quite another type. Again, an examination of the $\delta$-iron photograph shows that $\delta$-iron also has the same structure as $\alpha$-iron. Thus the strange fact is revealed that, although it has been considered that iron has four allotropic modifications, the transition points of which are about 750° C. ($\alpha \rightleftarrows \beta$), 900° C. ($\beta \rightleftarrows \gamma$), and 1,400° C. ($\gamma \rightleftarrows \delta$), yet it exists in two crystalline forms only, the body-centred cubic lattice for $\alpha$-, $\beta$-, and $\delta$-iron, and the face-centred cubic lattice for $\gamma$-iron. In other words, the transformation which takes place at 900° C. is reversed at 1,400° C. The fundamental (unit) cell of the body-centred cubic lattice is a simple cube having one point at each corner and one in the centre. The unit cell of the face-centred cubic lattice is the simple cube, having one point at each corner and one point at the centre of each face. For $\alpha$-iron at ordinary temperature the side of the unit cube is 2·87 A.U. At 800° C. it has increased to

2·90 A.U., and at 1,425° C. to 2·93 A.U., which agrees very well with the known coefficient of expansion of iron.

With regard to the space-lattice of iron in hardened steels, it was found that the $\gamma$-iron lattice of austenite steels is enlarged by the dissolved carbon, while the $\alpha$-iron lattice in martensite also seems to be influenced by the carbon present. If these results are to be relied on (the evidence is not exceptionally strong), they indicate that in martensite the carbon, as is generally supposed, is so intimately mixed with the iron that it may be considered to be a real atomic solid-solution. The breadth of the three very faint and diffuse lines in the martensite photographs seems to show that the individual pieces of homogeneous lattice in the steel are, on an average, only 20 A.U. or so across, which means that each of them contains only a few hundred atoms. Martensite can thus be considered to be on the verge of being totally amorphous.

An investigation has also been conducted with a view to determining the true crystalline form of cementite. Three different powders gave identical photographs, from which fact it may be concluded that the cementite in all three alloys used is probably composed of a unit chemical individual. With the aid of a Laue photograph, the crystals were assigned to the orthorhombic system. In each unit cell (compare acenaphthene above) there are four molecules of $Fe_3C$.

While on the subject of the X-ray spectra of metals, mention must be made of the graphical method devised by Hull and Davey (*Phys. Rev.*, vol. xvii, May 1921) for determining the crystal-structure of tetragonal and hexagonal crystals. In such crystals there is only one unknown parameter which is really essential to the symmetry, and that is the " axial ratio " ($c : a$). It is the ratio of the length of the vertical axis, $c$ (the tetrad axis in the tetragonal system, the hexad axis in the hexagonal system), to the length of the horizontal axis, $a$ (a dyad axis in both systems). The essence of the new method is to plot the logarithms of the theoretical spacings of the different planes as functions of the axial ratio, and to the graph so obtained to fit the logarithms of the observed spacings. The logarithms of the spacings are plotted all on the same logarithmic scale, so that they may be compared directly with experimental values without regard to the absolute lengths of the axes. By such means Hull has arrived at the crystalline structure of most of the common metals. His paper on the " X-ray Analysis of Thirteen Common Metals " (*loc. cit.*) is a very important contribution to the science.

In his work to date on organic crystals, Bragg, in order to demonstrate the physical existence of the benzene and other ring-formations, has confined himself to aromatic compounds:

The present author has recently commenced an investigation of several members of the other great division of organic chemistry, the fatty series.

In view of the interest which attaches to it in chemistry, physics, and crystallography, and its association with the great names of Biot and Pasteur, the problem of tartaric acid was attacked first (*Proc. Roy. Soc.*, now in press). The crystals of this compound belong to the monoclinic sphenoidal class, that is, they possess a dyad axis of symmetry only. Consequently the unit cell is shaped like that of naphthalene in Fig. 2, but the plane of symmetry parallel to OCGA is absent. The crystallographic data are:

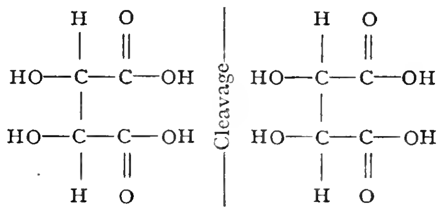
$$a : b : c = 1{\cdot}2747 : 1 : 1{\cdot}0266, \ \beta = 100° \ 17', \ \text{sp. grav.} = 1{\cdot}759.$$

X-ray analysis shows at once that there are two molecules to the unit cell, one at each of the corners and one lying somewhere along the line passing through the centres of the faces OCDB, AGEF. Because of the position of this second molecule, the observed lengths of the *b* and *c* axes are half the calculated lengths. The accurate lengths of the three axes are

$$a = 7{\cdot}693 \text{ A.U.}, \quad b = 6{\cdot}037 \text{ A.U.}, \quad c = 6{\cdot}195 \text{ A.U.}$$

All the other observed spacings agree with the theoretical values, which fact means that either (1) the second molecule does not lie exactly half-way between the faces OCDB, AGEF; or (2) if it does, its orientation is quite different from that of the molecules at the corners of the cell; or (3) both (1) and (2) hold. As a matter of fact, consideration makes it clear that if the tartaric acid molecule itself is completely devoid of symmetry, a single unit cell, with molecules at each of its corners, cannot possibly possess a dyad axis of symmetry. For the completed structure to show this element of symmetry, it requires the presence of *two* interpenetrating monoclinic lattices, either of which may be obtained from the other by a certain displacement and a rotation through 180°. Either of these two lattices alone is asymmetrical, but once they interpenetrate and extend through space, the appearance of the final arrangement is clearly unaltered by a rotation through 180° about the *b* axis. And that is what we mean when we say that tartaric acid shows a dyad axis. The second molecule must be the same as those at the corners of the cell, but rotated through 180° about the dyad (*b*) axis, because it is part of the second simple monoclinic lattice which interpenetrates the first and may be obtained from it by a certain displacement and a rotation through 180° about the dyad axis.

The facts afforded by the X-ray observation of tartaric acid are thus co-ordinated and linked up with the symmetry. The exact position of the second molecule is then fixed very nearly by measurement of the relative intensities of the various orders of reflection from the faces OCDB, AGEF in Fig. 2. It is found to lie just to the right of the centres of these faces. There remains now the means by which the two interpenetrating lattices are bound together. It would be impossible to give here a detailed account of the investigation of this part of the problem. The salient facts only may be enumerated. The molecules, of which the chemical structural formula is (*a* or *a′*)




(*a*) (*a′*)

lie lengthwise along the *a* axis, the length of the molecule fitting almost exactly with the observed probable " diameters " of the various atoms. The perfect cleavage (parallel to OCDB in Fig. 2) thus passes directly across the junctions between the hydrogens of the hydroxyl groups, a fact which at once recalls the similar cleavage in those organic bodies investigated by Bragg. The remaining junctions are effected between the (—H)'s and the ( ‖ O)'s, the (—H) of each molecule of one lattice linking up diagonally across the faces parallel to OCDB (Fig. 2) with the ( ‖ O) of each molecule of the other lattice (see Fig. 5).

But now let us consider the most important part of the structure, the dispositions of the various atoms constituting each molecule ; for in these must lie the explanation of those characteristic properties of tartaric acid which have so long excited scientific interest. As Pasteur pointed out over sixty years ago, whatever the arrangement of these atoms, it must be so ordered that an alternate arrangement is also possible, such that the relation between the two forms is as the relation of an object to its mirror-image. For tartaric acid, both in solution and in crystals, shows two distinct forms, one of which rotates the plane of polarisation of light to the right and the other to the left. Corresponding to this purely optical dimorphism is the crystallographic property of existing in two enantiomorphous forms, that is, in two forms, either of which is the mirror-image of the other across the symmetry plane of the system (OCGA in Fig. 2).

It is a remarkable fact that the details of the crystalline structure of tartaric acid bear out Pasteur's prophecy completely. There *are* two possible arrangements of the atoms of the molecule, both of which are in accord with the crystallographic and X-ray data, and either of which is the mirror-image of the other. Fig. 6 (*a* and *b*) shows these two enantiomorphous arrangements of the atoms (*a′* and *b′* are end views of the molecules shown lengthwise in *a* and *b*). Moreover, within the nucleus of each molecule is an irregular spiral

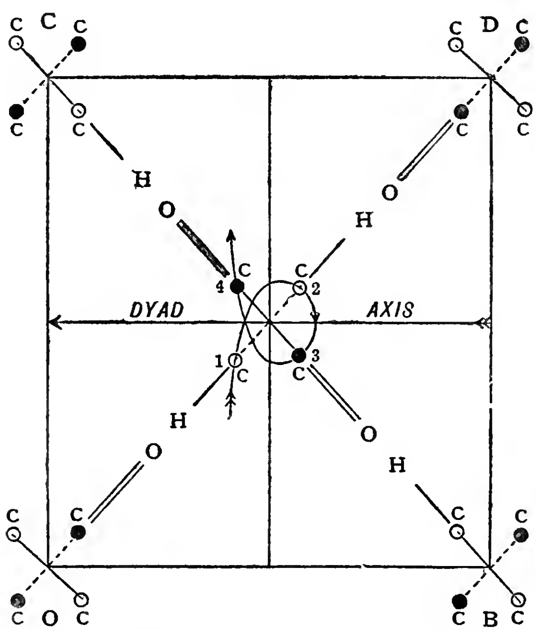



FIG. 5.—Showing end view of unit cell of tartaric acid.

formation of the four carbon atoms, to which we may ascribe the characteristic optical rotation of the tartrates. In one form the spiral is right-handed, and in the other left-handed. But the model of the structure leads us much farther than Pasteur's prophecy. There is yet another spiral formation of the four hydroxyl groups, which is in an opposite sense to that of the four carbon atoms of the nucleus. In the crystalline state, the existence of one spiral automatically brings about the existence of the other. And this significant fact appears to be at the root of a remarkable anomaly in the optical behaviour of tartaric acid.

As long ago as 1816, Biot observed that, whereas in quartz and other optically active bodies, the angle through which the plane of polarisation of light is rotated is, to a close approximation, inversely proportional to the square of the wave-length of the light employed (Biot's Law), in the case of tartaric acid this is by no means true, for the specific rotation of tartaric acid shows a well-defined maximum in the green portion of the spectrum. Since Biot's time many experiments have been performed to determine the cause of this anomaly, but, beyond the explanation put forward by Arndtsen in 1858, no real

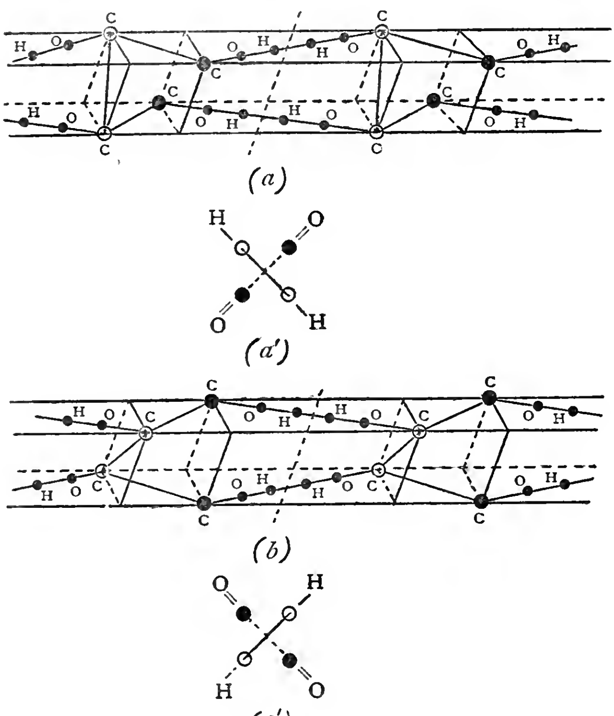
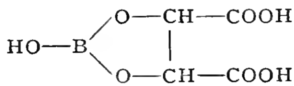



FIG. 6.—Showing enantiomorphous arrangements of atoms in tartaric acid.

physical basis for the phenomenon has been forthcoming. Arndtsen imagined a mixture of two substances, one of which was dextro- and the other lævo-rotatory, and, in addition, that the rotation of the first increased, as the wave-length of the light decreased, more rapidly than that of the other. It is clear that such a combination, dextro-rotatory in certain circumstances and lævo-rotatory in others, would simulate the properties of tartaric acid. For while aqueous solutions of ordinary tartaric acid are dextro-, the crystals of the same acid are lævo-rotatory. And, as we pass from dilute solutions on the one hand to the solid state on the other, the dextro-rotatory power gradually gives place to the lævo-rotatory power. Dilution, rise of temperature, or "fixing" the hydroxyl groups by the addition of boric acid to form boro-tartaric acid,




reduces and finally destroys the lævo-rotatory power. Cooling, concentration, solidification, or crystallisation reduces and finally destroys the dextro-rotatory power.

The crystalline structure of tartaric acid offers a simple but real physical explanation of all these facts. We have already indicated the two opposing spiral formations which are necessary and sufficient to account for the anomalous rotatory dispersion. The perfect cleavage of the crystals is a manifestation that the structure is ruptured across the junctions of the hydrogen atoms of the hydroxyl groups. In the complete structure these hydroxyl groups are linked together in such a way as to form a twisted arrangement of atoms. The act of solution or any departure from the crystalline form is sufficient to destroy the twisted arrangement. But the fact of crystal growth itself points to an initial leaning on the lart of the hydroxyl groups towards such an arrangement as holds in the crystalline form, and it is fairly safe to assume that the tendency of the molecules to build themselves up into a lattice exists even in dilute solutions. There will always be present strings of molecules, connected together at the hydrogen junctions, which will show to a certain extent those properties which are completely manifested only in the crystalline state. On dilution, ionisation and hydration will break up these strings more and more, and the dextro-rotatory effect of the nucleus will increasingly predominate.

In the paper mentioned above it is shown that it is impossible by the diffraction of X-rays to detect directly the difference between the dextro- and lævo-forms of the same chemical compound.

Some far-reaching theoretical considerations regarding the true significance of crystal-structure have just been brought forward by G. Shearer (*Proc. Phys. Soc.*, now in press). They mark the latest development and, in fact, a new era in the analysis of crystalline form. The connection between the symmetry of the molecule and of the lattice and the number of molecules contained in each unit cell is stated clearly in a few fundamental principles. This aspect of the subject has been already hinted at in the discussion above of the crystalline structure of tartaric acid, but to go into the whole question in detail would unduly prolong this article. However, the broad outlines may be stated very simply.

It is clear that a single space-lattice constructed of unsymmetrical units can show no symmetry by itself. A crystal built up on such a basis would simply obey the fundamental law of crystallography, the Law of Rational Indices, but nothing else. Calcium thiosulphate, $CaS_2O_3$, $6H_2O$, is supposed to be a case in point. The addition of any element of symmetry to a structure composed of unsymmetrical units necessarily involves the presence of another lattice, interpenetrating the first, and bearing to it the relation implied by that element of symmetry. For instance, as we have seen in the case of tartaric acid, the presence of a dyad axis means that there are, in the complete structure, two interpenetrating simple lattices, either of which can be obtained from the other by a displacement and a rotation through 180°. Similarly, the presence of a plane of symmetry involves the existence of two interpenetrating simple lattices, either of which can be obtained from the other by a displacement and a reflection across the plane of symmetry. And so, by the logical extension of this principle, we arrive at the conclusion that, for a crystal composed of unsymmetrical units, the number of molecules per unit cell is equal to the number of elements of symmetry shown by the crystal.

But suppose now the units are not unsymmetrical, that, in fact, they each possess definite symmetry of their own. Nature then makes use of it in order to reduce the number of molecules required to build up the unit cell. Indeed, it seems to be a general principle that Nature never uses more than the minimum number of molecules necessary to show the complete symmetry of the structure. For instance, if the molecules possessed each a dyad axis, this circumstance would be made full use of in a crystal possessing a dyad axis (that is, the dyad axis of the molecule would coincide with the dyad axis of the crystal), and if that dyad axis were the only element of symmetry shown by the crystal, then clearly no more than one molecule per cell would be necessary. Thus we see that, in general, the number of molecules per cell is only an expression of the relation between the symmetry of the complete lattice and the symmetry of the molecules constituting the lattice. It is simply the number of elements of symmetry shown by the crystal divided by the number of elements of symmetry shown by the molecules.

# GELATIN

By T. SLATER PRICE, O.B.E., D.Sc., F.I.C.
*Director of Research to the British Photographic Research Association*

Although gelatin, in the form of glue, has been known at least since the time of the Pharaohs of Egypt (Cf. Bogue, *Journ. Franklin Institute*, 1922, **193**, 795) the chemistry both of its preparation from bones and hides, and of its constitution, may still be said to be in its infancy. Belonging, as it does, to those complex substances, the proteins, its chemical investigation is a very difficult problem, and essentially progress has only been made in the examination of its degradation products, which consist mainly of amino-acids. Dakin (*Journ. Biol. Chem.*, 1920, **44**, 524) has so perfected the methods of degradation and separation of the amino-acids that he has succeeded in recovering 91·3 per cent. of the total nitrogen, as shown by the following table :

| | | | |
|---|---|---|---|
| Glycine | 25·5 | Phenylalanine | 1·4 |
| Alanine | 8·7 | Tyrosine | 0·01 |
| Leucine | 7·1 | Proline | 9·5 |
| Serine | 0·4 | Hydroxyproline | 14·1 |
| Aspartic acid | 3·4 | Histidine | 0·9 |
| Glutamic acid | 5·8 | Arginine | 8·2 |
| Lysine | 5·9 | Ammonia | 0·4 |

There are still, however, unidentified bases in the hydrolytic products of gelatin, as pointed out by van Slyke and Hiller (*Proc. Nat. Acad. Sci.*, 1921, **7**, 185). Attempts have been made by Prof. Procter and by J. A. Wilson to deduce a formula for gelatin, but as it has still to be proved that pure gelatin, as a unitary substance, has been obtained, such formulæ have very little significance.

In view of the complex chemical nature of gelatin it is not to be wondered at that the enormous literature on the subject consists, to a very great extent, of accounts of the results obtained in the investigation of its colloidal properties. Actually the word " colloid " is derived from the Greek word *κόλλα*, meaning glue, and at the time when this term was first used by Graham it was supposed that all colloids were substances of very complex constitution, just as is glue. As is well known, however, this is by no means the case, since the suspensoid colloids may consist of the elements themselves, *e.g.*, colloidal gold and silver. Suspensoid sols are practically as mobile as water itself, that is, the colloidal particles hardly alter the viscosity of the dispersion medium, but emulsoid sols, of which gelatin is a typical example, show large viscosity values, even in comparatively low concentrations, and with increase in concentration the viscosity increases enormously, whereas there is only a small increase in the viscosity with suspensoid sols under similar conditions. Also when a gelatin sol is cooled down it is well known that it sets to a jelly, whereas no such change takes place with a suspensoid sol, such as that of gold, when treated in the same way. Moreover, the change from sol to gel is reversible, since on warming the gel it liquefies readily to a sol. Again, if the gel is dried and then immersed in water it imbibes water and swells to a greater or lesser extent.

Naturally it was such physical properties as those just mentioned, namely, viscosity and swelling, which were the earliest investigated, and it was soon found that the relations were very complicated, depending on previous history, even in systems made up from gelatin and pure water alone. For example, shaking, or repeated passage through a viscometer, will decrease the viscosity of a gelatin sol ; at ordinary temperatures the viscosity of a freshly made sol gradually increases, whilst that of a freshly diluted sol gradually decreases ; in a freshly made gel or sol the intensity of the Tyndall cone gradually increases ; and so on. All such phenomena are indicative of the formation of a structure and of the attainment of an equilibrium of some kind, and complicate the investigation of gelatin very considerably.

As an example of the complicated nature of swelling the following quotation may be given from Bancroft's book on *Applied Colloid Chemistry* : " If dried gelatin is placed in cold water it swells considerably, and may take up ten times its weight of water ; but there are no experiments to show that it would ever go up say to an 8 per cent. gel. On the other hand, it is possible to start with an 8 per cent. gel and dry it to a 96 per cent. gel, after which it will take up water rapidly to an 8 per cent. gel. This means that the structure of the gelatin plays an important part in the rate of swelling. This is confirmed by some unpublished preliminary results of Mr. Cartledge. Gelatin gels were made up containing 8, 16, 24 and 32 per cent. of gelatin. These were all dried at room temperature to about 96 per cent. concentration. When water was added each swelled rapidly to the original concentration and then took up water slowly. If these results are accurate, it means that the four 96 per cent. gels were all different, and that the 8 per cent. gel did not become like the 16, 24, or 32 per cent. gel while being dried." Similar experiments have been recorded by Procter (*Journ. Chem. Soc.*, 1914, **105**, 313) and have been confirmed by Sheppard and Elliott (*Journ. Amer. Chem. Soc.*, 1922, **44**, 373). In connection with such experiments, reference is often made to a swelling maximum, but the existence of such a maximum has never been proved. Brotman (*Journ. Soc. Leather Trades Chemists*, 1921, **5**, 226) has shown that the imbibition of water by gelatin can be increased by dispersion of the gelatin. Pure, air-dry gelatin swells to a so-called maximum amount in about twenty-four hours, the maximum varying according to the variety of gelatin used. If the equilibrium gel is then dispersed by placing the test tube containing it in hot water (at about 80°) for two minutes, and then allowed to set again, further swelling will take place on immersion in the previous swelling water.

If the results obtained with gelatin in pure water are so complicated, it is no wonder that they are still more so in the presence of acids, bases, and salts. This may be illustrated by comparatively simple experiments, which are cited from Wo. Ostwald's book on *Theoretical and Applied Colloid Chemistry*. A 2½ per cent.[1] solution of gelatin, set to a jelly in a test tube, can be detached from the sides of the tube and broken into pieces by hard shaking. If, however, several per cent. of magnesium sulphate are added to the sol before setting, the resulting gel can no longer be broken up by shaking. On the other hand, if sufficient potassium iodide is added to the sol it will not set and remains fluid. Sulphates, citrates, and phosphates act similarly to magnesium sulphate, that is, they increase the viscosity of gelatin, and to a much greater degree than they do that of pure water. Bromides and cyanides act similarly to iodides. Organic substances also act differently, for example, chloral hydrate and urea decrease the viscosity, whilst alcohol, in small amounts, increases it.

Similar results would be obtained if, instead of using a gel, the viscosity of the sol were measured in a viscometer. Such measurements would show, however, that further complications arise, in that there may be either an increase or a decrease in the viscosity, depending on the concentration of the added salt. For example, sodium chloride in medium concentration (about N/4) produces a viscosity which exceeds that of pure gelatin, whereas at higher and lower concentrations the viscosity is less than that of pure gelatin.

[1] The concentration necessary to give these results will depend on the kind of gelatin used.

This, however, is much better shown in the case of the influence of acids and alkalis, as is illustrated by the following figures, which are due to von Schroeder.

| Concentration of HCl or NaOH | 0 | N/512 | N/256 | N/128 | N/64 | N/32 | N/16 | N/8 | N/4 |
|---|---|---|---|---|---|---|---|---|---|
| Rel. Viscosity HCl | 1·40 | 1·55 | 1·76 | 1·68 | 1·58 | 1·42 | 1·25 | 1·17 | 1·12 |
| Rel. Viscosity NaOH | 1·40 | 1·52 | 1·60 | 1·79 | 1·62 | 1·38 | 1·25 | 1·10 | 1·10 |

Simple swelling experiments may be carried out as follows: A series of gelatin discs of the same size and weight are prepared by pouring a concentrated gelatin sol on a glass plate, allowing it to set, and then cutting the set gelatin into discs or squares, and drying. If separate discs are then immersed for twenty-four hours in solutions of N/20-HCl, N/20-NaOH, N/2-KI, N/5-$CaCl_2$, water, and saturated magnesium sulphate respectively, it will be noticed that the order in which swelling has been favoured is: acid > alkali > potassium iodide > calcium chloride > water > magnesium sulphate; the disc in the acid solution will be swollen to about twice the size of that in pure water.

In connection with swelling an interesting experiment of Fischer's may be quoted, which throws light on the local swelling which takes place when one is stung by a nettle or a jelly fish. A 6 per cent. gelatin solution is set in a Petri dish, and then infected at various points with formic acid by piercing the gel with a capillary tube containing a concentrated solution of the acid. Water is then poured over the gelatin, and after one or two hours it will be seen that the parts which were infected are more strongly swollen than other parts.

The results of investigations such as those indicated led to the putting forward of what are known as Hofmeister series, Hofmeister being the one who first studied such effects. For example, the effect of equivalent (tenth-normal) solutions of various acids on the swelling is indicated by the following series: HCl > $HNO_3$ > acetic acid > $H_2SO_4$ > boric acid. With the sodium salts of various acids the swelling decreases in the order: Thiocyanates > iodides > bromides > nitrates > chlorates > chlorides > acetates > tartrates > citrates > sulphates.

Such series are very difficult to understand, since the order of the compounds does not bear much relation to their ordinary properties; it is difficult, for example, to comprehend why acetic acid comes between nitric and sulphuric acids.

It is the realisation that gelatin does not behave simply as a colloid, but also has amphoteric properties, which has brought order out of chaos in recent years. For progress in this direction we are chiefly indebted to the work of Procter in England, Pauli in Austria, and Loeb in America.

Gelatin is a stronger acid than base, so that acid has to be added to its solution in water to bring the gelatin to the isoelectric condition. At the isoelectric point the hydrion concentration ($C_{H\cdot}$) of the solution is approximately $2{\cdot}5 \times 10^{-5}$, that is, the pH ($= -\log C_{H\cdot}$) [1] is about 4·7, which is on the acid side of the neutral point of water (pH = 7·0). The theory of amphoteric electrolytes shows that at the isoelectric point their solutions should contain a maximum number of neutral particles and should therefore possess peculiar properties; in accordance with this it has been found that the properties of swelling, viscosity, osmotic pressure, etc., show a minimum at that point, whilst the precipitation by alcohol is most pronounced. A 1 per cent. solution of isoelectric gelatin is at first transparent. After some time, which is the shorter the lower the temperature, the solution becomes opaque and in the course of time a precipitate may deposit; raising the temperature again gives a clear solution. The setting of the solution to a gel is a different process from this precipitation, since cloudiness or opacity is not necessarily connected therewith.

On the acid side of the isoelectric point (pH $< 4{\cdot}7$) gelatin should behave as a base and form gelatin acid salts, whilst on the alkaline side (pH $> 4{\cdot}7$) it should act as an acid and form metal gelatinates. Loeb has endeavoured to show that this is true in several ways, of which the following may be quoted. Separate quantities of 1 gram each of powdered gelatin (going through sieve 60, and not through sieve 80) are brought to different hydrion concentrations by putting them for 1 hour at about 15° C. into 100 c.c. of nitric acid solutions varying in concentration from M/8, M/16 . . . down to M/8192. After filtering and allowing the acid to drain off, they are washed once or twice with 25 c.c. of water at 5° C. to remove acid remaining between the granules. The different portions, which now possess different pH's, are then put for an hour into beakers containing M/64 silver nitrate at a temperature of 15° C., after which they are separately collected on a filter and washed 6 to 8 times, each with 25 c.c. of ice-cold water. This washing removes the silver nitrate held in solution between the granules, since the silver in combination with the gelatin is not thus removed (or at least only very slowly by altering the pH). The separate quantities are then

[1] For the meaning of pH see the article on "Soil Reaction," by Fisher, SCIENCE PROGRESS, 1922, No. 63, pp. 408–25.

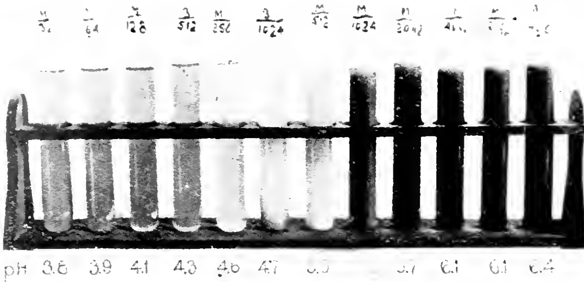
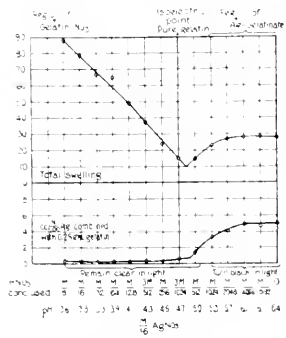


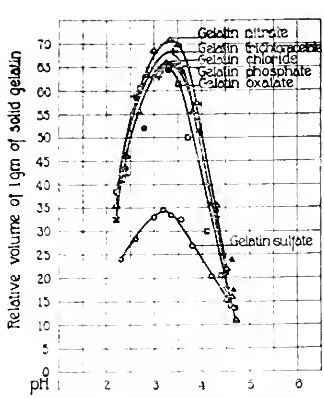

FIG. 1.




Gelatin treated with different concentrations of $HNO_3$, from M/8 to M/8192, washed, and then treated with the same concentration of $AgNO_3$ (M/16), and then washed again. Abscissæ show concentrations of acid used. The final pH of the gelatin solution is found under the figure for the concentration of acid used.

The ordinates of the lower curve give the values for the silver found in combination with the gelatin. The curve shows that at the isoelectric point (pH = 4.7) and on the acid side of the isoelectric point, the gelatin was practically free from silver. On the more alkaline side the amount of silver found in combination with the gelatin increased with the pH. This proves that gelatin can combine with a cation only on the alkaline side from the isoelectric point, and this is corroborated by the fact that on the alkaline side from the isoelectric point only was the gelatin darkened by light. The ordinates of the upper curve are the values for the swelling of the same gelatin. On the alkaline side from the isoelectric point, where the gelatin had combined with silver, the curve for swelling runs parallel to the curve for silver gelatinate formed. It was, therefore, the relative mass of silver gelatinate formed which determined the physical properties of gelatin.

FIG. 2.




Influence of HCl, $HNO_3$, $H_3PO_4$, $H_2SO_4$, trichloracetic, and oxalic acids on the swelling of gelatin. Abscissæ are the pH, ordinates the volume of gelatin. The curves for all the acids are practically identical except that for $H_2SO_4$ which is about one-half as high as the curves for the other acids.

FIG. 3.

melted at 40° C., diluted to 100 c.c and portions of each put into test-tubes and exposed to light, the previous manipulations having been carried out in a dark room. The pH's of the solutions remaining are also determined, and also the quantities of silver remaining in them. In 20 minutes all the gelatin solutions with a pH $> 4{\cdot}7$, that is, from pH 4·8 and above, become opaque, and then black, while all the solutions of pH $< 4{\cdot}7$ remain transparent, even when exposed to the light for months or years. The solutions of pH 4·7 become opaque, but remain white, no matter how long they are exposed to light; at this pH—the isoelectric point—gelatin is not in combination with silver, but it is insoluble. Hence the cation, silver, is only in combination with gelatin when the pH is $> 4{\cdot}7$. The accompanying figure (Fig. 1) is a photograph of a set of test-tubes thus prepared. It should be noticed that in all cases the pH of the various solutions is on the acid side of the neutral point, pH = 7.

The analytical figures are given in the following table, and illustrated in Fig. 2, which at the same time shows the variation in swelling of gelatin at different pH's.

*c.c.* 0·01 *N-Ag in combination with* 0·25 *gm gelatin at different pH's*

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH . | 3·6 | 3·7 | 3·9 | 4·1 | 4·3 | 4·6 | 4·7 | 5·0 | 5·3 | 5·7 | 6·1 | 6·4 |
| c.c. . | 0·5 | 0·3 | 0·3 | 0·2 | 0·2 | 0·2 | 0·55 | 1·25 | 3·2 | 4·0 | 4·85 | 4·9 |

Results similar to those with silver nitrate are obtained when a nickel or copper salt is used. With potassium ferrocyanide the gelatin retains the ferrocyanide, as gelatin ferrocyanide, on the acid side of the isoelectric point, the gelatin turning blue after a few days, owing to the formation of ferric salt.

Another deduction which can be made in connection with the pH of gelatin solutions is that if the effects on swelling, viscosity, etc., of various monobasic acids (HCl, HBr, $HNO_3$, $CCl_3 . COOH$, etc.), and acids such as succinic, tartaric, citric, and phosphoric acids, which dissociate only into two ions at ordinary dilutions, are compared at the same pH, they should be the same; dibasic acids which dissociate into three ions at ordinary dilutions, such as sulphuric acid, should give different effects. The accompanying figure (Fig. 3) shows that within the error of experiment this is the case for swelling, and it has been shown to hold for other physical properties. If the curves are compared with those which would be expected on the basis of the Hofmeister series, those for phosphates, oxalates, citrates, and tartrates should be in the region of the sulphate curve.

Similar results are obtained with the alkalis; the curve for the weak base ammonium hydroxide is the same as that for the strong bases, lithium, sodium, and potassium hydroxides, when plotted with pH as abscissæ, whilst the curve for calcium and barium hydroxides are considerably lower.

Salts such as sodium acetate, which give an alkaline solution in water, owing to hydrolysis, have an abnormal effect on the swelling, etc., of gelatin, when compared with, say, sodium chloride. Loeb has shown that this is due to the alteration of the pH of the gelatin solutions when the salt is added; when compared at the same pH, sodium chloride and sodium acetate have the same effect.

The above results, and many others, indicate the necessity of knowing the pH when investigations are carried out, and show that when comparisons are made under the proper conditions the Hofmeister series, with their anomalies, disappear.

The increased swelling, viscosity, etc., which take place on either side of the isoelectric point, and reach a maximum [1] at pH's of about 3·5 and 8·5 respectively, are attributed by Pauli to the greater hydration of the gelatin ions formed, as compared with that of the neutral molecule, but Loeb is not in agreement with this. The latter postulates the existence in any protein solution of molecularly dispersed particles, floating side by side with submicroscopic particles occluding water, the amount being regulated by the Donnan equilibrium (Procter was the first to apply the Donnan equilibrium to the study of gelatin solutions). The osmotic effects are determined by the molecular particles, the viscosity effects by the submicroscopic particles. Any influence in the solution, *e.g.*, change in the hydrion concentration, by which the molecular dispersion is increased at the expense of the solid particles, will result in an increase in the osmotic pressure and a decrease in viscosity, and the opposite conditions will result in the reverse of these effects.

The structure of gels has been a bone of contention for a long time. Bogue (*Journ Amer. Chem. Soc.*, 1922, **44**, 1343) has given a summary of the various views which have been held, which may be stated briefly as follows: Nägeli assumed that gels were two-phased, and that the solid phase was crystalline, but Sherrer has not found any indication of crystalline structure in gelatin, when examined by the X-ray method. Bütschli and van Bemmelen have advocated a cell-

[1] Pauli and Loeb give different explanations of the maximum, but these will not be entered into now.

like structure of definite form, hanging together at certain points, forming a network, and Hardy concluded that the solid phase consists of a solid solution of water in gelatin, and the liquid phase a solution of gelatin in water; Wo. Ostwald has put forward the idea of a two-phase liquid-liquid system. Procter postulates the existence of a solid solution of the exterior liquid in the colloid in which both constituents are within the range of the molecular attractions of the mass, and Loeb has extended the idea of Procter. At the present time the idea of a fibrillar structure, as advocated by McBain and his co-workers for soaps, is gaining ground, and is especially supported by Bogue in America and Moeller in Germany.

The question of the structure of the gel is intimately bound up with that of the constitution of the sol. Reference has already been made to phenomena which indicate the existence of a structure in the sol, and it may be mentioned that various investigators have obtained results showing the existence of torsional stress in dilute sols (Schwedoff, *Journ. de Physique*, 1889, **8**, 341; Colin, *Comptes Rendus*, 1893, **116**, 1251; Garret, *Phil. Mag.*, 1903, **6**, 374; Rohloff and Shinjo, *Physik. Zeitschr.*, 1908, **8**, 442). The particular structure assigned to gelatin will have to account for the fact that there is a gradual and regular and not a sudden change in properties when the transformation of sol into gel, and vice-versa, takes place. The so-called setting and melting points of gelatin are not specific points as they are with crystalloids; an appreciable time factor enters into their determination and the two points do not coincide. To quote Sheppard and Sweet (*Journ. Ind. Eng. Chem.*, 1921, **13**, 423), "both the melting point and the setting point are more or less arbitrary conceptions, and their determination depends mainly upon standardised experimental conventions."

In the solutions of gelatin there seems to be present both the sol and gel forms in some kind of equilibrium. It has long been known that whilst dilute solutions (1 per cent.) of pure gelatin would gel at low temperatures (10° C.), yet above certain temperatures, roughly estimated at about 35° C., gelation would not take place at any concentration, although exceedingly viscous solutions might be obtained. C. R. Smith (*Journ. Amer. Chem. Soc.*, 1919, **41**, 146; *Journ. Ind. Eng. Chem.*, 1920, **12**, 878) has investigated the mutarotation of gelatin and shown that at temperatures above 33° to 35° C. the specific rotation of gelatin has a practically constant value of about −123°, whilst below 15° C. it is practically constant at about −266°. At all temperatures between 35° and 15° the rotation varies between these limits, and Smith draws the conclusion that in aqueous solution gelatin exists in two modifications, one of which is stable above 33° to 35° C., and is denoted as "Sol form A," whilst the other is stable below 15° C., and is called "Gel form B." Between 15° and 35° C. a condition of equilibrium exists between the two forms, and the mutarotation observed is considered to be due to the transformation of one form into the other by a reaction which is reversible with the temperature. In a more recent paper, Davis and Oakes (*Journ. Amer. Chem. Soc.*, 1922, **44**, 464) have reported that at 38·03° C. gelatin sol and gelatin gel can exist in equilibrium, but that this is not true for any other temperature. For example, a "seeded" solution (one to which a little gelatin had been added) showed no change in viscosity with time at the temperature of 38·03°. At any temperature below this a regular increase in viscosity with time was observed. At higher temperatures a decrease occurred until the viscosity equalled that of a similar unseeded portion at the same temperature. Bogue, however (*Journ. Amer. Chem. Soc.*, 1922, **44**, 1313), has measured the change in viscosity with time of gelatin solutions at varying hydrion concentrations and under different degrees of purity, and found that there are several factors influencing the effective volume, that is, the equilibrium of the gelatin in solution. These include the hydrion concentration (pH), the amount and nature of the inorganic ions present, and the products of gelatin hydrolysis. In another series of experiments Bogue measured the viscosities of gelatin solutions at varying temperatures, using a MacMichael viscometer at varying speeds of rotation. He found that if the curves showing the relation between the viscosity and the number of revolutions per minute were extrapolated towards the origin, at temperatures above 34° they met the origin, but below this temperature they intercepted the viscosity axis at distances which were all the greater the lower the temperature. Also, the lower the concentration of the solution, the lower the temperature at which the extrapolated curves still met the origin. These experiments indicate that plastic flow becomes evident in a gelatin solution (25 per cent.) at about 34° C.; that the transition from the sol to the gel condition is a gradual and not a sudden change, and that in solutions at temperatures below 34° both the sol and gel forms exist together.

It is obvious from the above that there has been considerable progress made in the investigation of gelatin, but that there still remains much to be done. As far as the physical properties are concerned, the quantitative investigation seems to have passed through three phases; in the first phase gelatin was treated mainly as a colloid, in the second mainly as an amphoteric electrolyte, and now, in the third phase, it is being realised that both the amphoteric and colloidal properties must be taken into account. Both of these last properties play a part in industrial applications; for example, the action of gelatin as a protective colloid is of great importance in the preparation of photographic emulsions; but in the operations of developing and fixing, its behaviour as an amphoteric substance must be considered, as may readily be realised when one remembers that the usual developers are alkaline and that acid fixing baths are often used; the swelling of the gelatin film will vary in the baths, and in the change from the developer to the fixing bath the gelatin must, at some time, pass through the isoelectric point (*compare* Sheppard, *Brit. Journ. Phot.*, 1922, in the press). Questions of the hardening and tanning of gelatin also arise, but these have not been touched upon in this article.

# SOME CHARACTERISTICS OF THE VIRUS DISEASES OF PLANTS

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The occurrence in plants of diseases caused by filterable viruses was first demonstrated by Iwanowski [1] in 1892 and fully established by Beijerinck [2] in 1898. Their studies showed that the juice of tobacco plants infected with the "mosaic" disease was capable of communicating the disease to healthy plants after passage through the Chamberland filter. Similar mosaic diseases are now known in a number of plants.

A little earlier than this, however, Erwin F. Smith [3] had investigated a very serious peach disease in the United States, and conclusively established the fact that, though no parasitic organism could be detected, a communicable virus was present in the diseased parts, and could be artificially transmitted to healthy trees provided organic union (as by budding diseased buds on healthy wood) was effected. Unlike tobacco mosaic, the virus of "peach yellows" has never been extracted and handled, nor is any other method of transmission established than that by organic union, though it is evident that other methods exist in nature since the disease is highly infectious and even has periods of epidemic outbreak. Whether the other two allied diseases of the peach subsequently described under the names "peach rosette" and "little peach" are regional effects of the same common cause or are distinct diseases is not certainly known.[4] The "peach yellows" type of disease has since been found in a few other cases, chief

[1] Iwanowski, D., *Bulletin de l'Academ. Imper. d. Science St. Petersbourg*, N.S., v, p. 67, 1892.

[2] Beijerinck, M. W., Over een Contagium vivum fluidum als oorzaak van de Vlekziekte der Tabaksbladen, *Verhand. Kon. Akad. van Wetensch. Amsterdam*, 2nd Sect., vi, 5, 1898.

[3] Smith, Erwin F., Peach Yellows: a Preliminary Report, *U.S. Dept. of Agric., Bot. Division, Bull.*, ix, 1888; Additional Evidence on the Communicability of Peach Yellows and Peach Rosette, *ibid.*, *Division of Veg. Path. Bull.*, i, 1891.

[4] Blake, M. A., Cook, M. T., and Connors, C. H., Recent Studies on Peach Yellows and Little Peach, *New Jersey Agric. Exper. Stat. Bull.*, 356, 1921.

amongst which is the "spike" disease of the sandalwood tree in India.[1], [2], [3].

It has been known for more than a century that it is sometimes possible to communicate variegation of the foliage of plants to non-variegated plants in the same manner as that mentioned in the last paragraph, namely by grafting a variegated branch on a stock with normal green leaves. Subsequent work by Lindemuth,[4] Baur,[5] and others has established the existence of several examples of this communicable variegation, which Baur calls "infectious chlorosis." It is characterised by a deficient development of chlorophyll, but the plants are not sickly, though less resistant to unfavourable conditions than the normal individuals. The infectious types are not usually propagated by seed, though certain other quite similar variegations that are non-infectious are reproduced in the seedlings. Except for the innocuous nature of infectious chlorosis and the fact that spread to neighbouring plants does not occur in nature, so far as is known, there are obvious similarities between this condition and the group of diseases of which "peach yellows" is a type.

In none of the groups mentioned above has any definite lesion been detected in the tissues of the affected plants, except in one form of potato mosaic ("crinkle") and in mosaic of maize, where some of the cells of the parenchyma may be affected. Arrested development of tissues or whole organs, localised hypertrophies, and malformations are not uncommon, but there is usually no definite necrosis of the cells in the earlier stages of the disease. In the later stages necrosis and death may take place—peach yellows, for instance, is invariably fatal—but this appears to be a generalised result of malnutrition, and not due to the local action of any specific toxin. There is, however, a group of diseases of the virus type characterised by a localised necrosis of a particular tissue, of which leaf roll of potato is the best known example.[6], [7], [8]. In this case there is a

[1] Barber, C. A., Report on Spike Disease in Sandalwood Trees in Coorg, *Indian Forester*, xxix, p. 21, 1903.

[2] Butler, E. J., Report on "Spike" Disease among Sandalwood Trees, *ibid.*, Appendix Series, 1903.

[3] Coleman, L. C., Spike Disease of Sandal, *Bull. Dept. of Agric. Mysore State, Mycol. Ser.*, No. 3, 1917.

[4] Lindemuth, H., Studien über die sogenannte Panaschüre, etc., *Landw. Jahrb.*, xxxvi, p. 807, 1907.

[5] Baur, E., in *Ber. d. Deutsch. Bot. Gesellsch.*, xxii, p. 453, 1904; xxiv, p. 416, 1906; xxv, p. 410, 1907; xxvi, p. 711, 1908.

[6] Quanjer, H. M., The Mosaic Disease of the Solanaceæ, its Relation to the Phloem-necrosis and its Effect on Potato Culture, *Phytopathology*, x, p. 35, 1920 [Bibl.].

[7] Schultz, E. S., and Folsom, D., Leaf Roll, Net-necrosis, and Spindling-sprout of the Irish Potato, *Journ. of Agric. Res.*, xxi, p. 47, 1921.

[8] Papers by Quanjer, Cotton, Murphy, and others in *Rep. Internat. Potato Conference of* 1921, Royal Hort. Soc., London, 1922.

definite pathological condition of that part of the vascular strands through which the elaborated food is conveyed to the growing or storage parts. The cell walls of the phloem swell and turn yellow and are altered in their chemical composition. Associated with this is an impairment of the function of the phloem characterised by failure to convey the normal food constituents from the leaves in which they are formed to the growing tissues in which they are required. The leaves remain choked with starch when those of normally functioning plants growing alongside are empty. Phloem-necrosis has actually been detected in only a few cases : in leaf roll of potato, sereh disease of sugar-cane, mulberry dwarf in Japan, mosaic disease of the sugar beet, the sieve tube disease of coffee in Surinam, and the brown bast disease of rubber. In certain other cases, however, particularly in peach yellows and the allied spike disease of sandal, there is such a marked interference with the translocation of starch from the leaves that there would seem to be some functional disturbance in the phloem, though hitherto no necrotic changes have been described.

Taking these four groups, and a few cases in which it is as yet uncertain whether the diseased condition is transmissible to healthy plants and if so in what manner, there are altogether some seventy or eighty genera of plants belonging to about thirty families which are affected by one or more of these diseases, and the number is rapidly being added to. As knowledge increases, it is probable that the rough classification here given will have to be modified : in particular the peach yellows type may be merged in the phloem-necrosis group.

## Methods of Transmission

All of the cases that have been tested so far are transmitted to healthy plants by budding, grafting, or other organic union between diseased and healthy plants. Transmission by mere contact of uninjured surfaces has not yet been detected in any case.

The next most general method of transmission is by means of sucking insects, generally green-fly (aphids). This has not been established in the case of the infectious chlorosis group, and there appears to be no evidence that this type is transmitted in any other way than by organic union. On the other hand, in the peach yellows group, though no other method of transmission has been artificially accomplished than by organic union, there is the clearest possible evidence that natural spread occurs freely, and my own experiments in the case of spike disease of sandalwood lead me to believe that insects will ultimately be found to be responsible. In the other two groups, comprising by far the greatest number of the diseases here referred to, insect transmission is fully established in a number of cases and is probably general.

Less common is transfer by direct inoculation with the juice of the infected plants. It is only certainly known to occur in the mosaic group. All attempts to secure infection in this way have failed in the peach yellows and phloem-necrosis groups, nor does there appear to be any evidence of it in the infectious chloroses.

Transmission through the seed is rare. It is only certainly known to occur in a few cases of mosaic diseases, *e.g.* in beans and clover, and occasionally in cucumbers, and in the mosaic-like disease of *Datura* mentioned in the next paragraph. It does not occur in most of the mosaic diseases tested, but is perhaps doubtful in one or more of the Solanaceæ affected with mosaic, especially one form of tomato mosaic.[1]

Amongst the most interesting cases of transmission by grafting is the recently described " quercina " disease of *Datura stramonium*.[2] It is fully infectious by grafting on healthy plants of this species, and spreads also in the field in some way unknown. Tested on a number of related species it was transmitted by grafting to a few in a mild form, producing little effect on the host. From the latter it could (in some cases at least) be transmitted back to healthy *Datura* plants. On immune species the virus failed to pass through as little as 3·6 cm. of the stem to reach a normal *Datura* graft in the stem near by. In the leaf roll of potato, also, allied species such as tomato can be infected by grafting, but the symptoms are less marked than on the potato or may even be entirely absent, though a graft is capable of transmitting infection back to the potato. Several such cases of " carriers " have been demonstrated in other virus diseases of the Solanaceæ. Even in the case of the infectious chlorosis group a similar phenomenon has been observed by Baur. When scions of an apparently immune species of *Abutilon* are grafted on *A. thompsoni* plants affected by chlorosis, they remain apparently healthy and show no symptoms. But they are capable of transmitting the disease to susceptible species grafted on them. On the whole, the examination of the experiments on transmission by grafting throws little light on the nature of these diseases, except that it gives room for speculation as to what the nature of a virus that requires organic union of the tissues for its passage can be. Possibly it is a parasite of the highly specialised type known in

[1] Westerdijk, Johanna, Die Mosaikkrankheiten der Tomaten, *Meded Phytopath. Labor.* " *Willie Commelin Scholten,*" i, 1910.

[2] Blakeslee, A. F., A Graft-infectious Disease of *Datura* resembling a Vegetative Mutation, *Journ. of Genetics*, xi, p. 17, 1921.

some plant rusts and mildews that needs the infected host cell to be alive and in normal health for its support and fails to maintain itself in weakened or dying cells. Wound infections, such as inoculation pricks, may fail in such cases by injuring the host cells, and only the infections of uninjured cells, with the establishment of symbiotic relations between living host and parasite, succeed.

The study of insect transmission is more helpful. Until it was discovered, there were many who held that no living organism need be invoked to account for the origin and infectious nature of these diseases, and there are still some supporters of the "enzymic" theory of mosaic disease who believe that the whole disturbance is due to nutritional disorders consequent on the introduction of some stimulus of a non-living nature that upsets the balance of the enzymic activities of the plant.[1] But the continued extension of some of these diseases to new areas, the rapid multiplication of the virus in the plant, its capacity to cause infection at very high dilutions sometimes exceeding 1 to 10,000, its power of unlimited transmission to new healthy individuals, its conveyance by insects and other points of similarity to certain virus diseases of animals, and above all, the discovery that the insect carrier may not become immediately infective after feeding on a diseased plant but requires a period of time before it is capable of transmitting the disease, have convinced most plant pathologists that, as Quanjer has recently put it in surveying these diseases, "One can hardly deny the existence of a whole world of ultra-microscopic organisms, causing them" (*Rept. Intern. Potato Conf. of* 1921, p. 138).

Undoubtedly the most important case in this connection is the "curly top" disease of beet, the first in which insect transmission was established.[2], [3]. The disease is only known to be transmitted by grafting and by the beet leaf-hopper, *Eutettix tenella*. After the latter has fed on diseased plants, it is not infectious for a period of from four to forty-eight hours. The shorter periods are obtained only at high temperatures. This is a clear case in which the infective agent requires to undergo some change or development in the insect transmitter before it can reinfect its plant host. If fed for only a short time on a

[1] Chapman, G. H., Mosaic Disease of Tobacco, *Massachusetts Agric. Exper. Stat. Bull.*, 175, 1917. Several of the recent German workers on the leaf roll and mosaic diseases of potato do not find it necessary to invoke the intervention of a living parasite in these diseases.

[2] Rand, F. V., and Pierce, W. D., A Co-ordination of our Knowledge of Insect Transmission in Plant and Animal Diseases, *Phytopathology*, x, p. 216, 1920.

[3] Severin, H. H. P., Minimum Incubation Periods of Causative Agent of Curly Leaf in Beet Leaf-hopper and Sugar Beet, *Phytopathology*, xi, p. 424, 1921.

diseased plant, the insect frequently fails to transmit the infection. It would appear that either the infective agent is not always in a condition to be taken up by the insect, or it is not always present in the tissues where the insect feeds, or possibly the insect itself is not always willing to feed in the proper way or is otherwise not always liable to take it up. On the other hand, a single leaf-hopper fed for five minutes on a diseased leaf has been recorded to be capable of causing the disease when transferred to a healthy plant. The disease can be transmitted to a number of other plants belonging to various families on which the leaf-hopper can feed, and some of these serve as a means of carrying the disease through the period of the year when there are no beets growing. The insect itself may remain infective for as long as 111 days after feeding.

In most cases that have been examined, however, the insect appears to be capable of transmitting the disease immediately after feeding, even though in several of these cases the juice of the diseased plant has not hitherto been found able to cause infection. The evidence in these last cases is not, however, very complete, and it is somewhat surprising that so important a question has been left unanswered in the case of the leaf roll and crinkle of potato, mosaic and leaf curl of raspberries, and the mosaic disease of the sugar beet. In these cases inoculations with the juice have failed, and if the insect transmitter does not become infective for some time after feeding, one would be led to suppose that there is a necessary part of the life cycle of the parasite in the insect, and so to understand why a direct transfer by juice is ineffective. Where direct inoculation by juice is successful, as in a number of the mosaic diseases (tobacco, potato, tomato, bean, clover, sweet pea, cucurbits, spinach, turnip, sugar-cane, etc.), it is evident that no essential part of the life cycle has to be passed in the insect host.

In spinach blight, a disease which appears to be of the mosaic type (though, unlike most other mosaic diseases, it is fatal), various interesting points in connection with insect transmission have been established.[1] It is carried by several insects (at least two species of aphids and the tarnished plant bug *Lygus pratensis*) and is also transmitted by direct inoculation with the juice of infected plants. The juice of the crushed aphids that have fed on diseased plants is infective. Infection can result if infective aphids are allowed to feed on healthy plants for only five minutes, and non-infected aphids can pick up the virus by feeding on blighted leaves for only ten minutes. Adult aphids are more infectious than those that are immature and the incubation period of the disease in the plant is shorter

[1] McClintock, J. A., and Smith, L. B., True Nature of Spinach-blight and Relation of Insects to its Transmission, *Journ. of Agric. Res.*, xiv, p. 1, 1918.

after infection by adults than by young. Several other conditions influence the length of the incubation period ; it is about twice as long, for instance, when the virus is taken from plants in an early stage of the disease than when taken from the later stages, though the percentage of successes on inoculation is about the same. After the aphid becomes infective it can carry the disease to several successive plants by feeding on each for a time. The progeny of the infected aphids kept from feeding on infected plants can transmit the disease up to at least the fourth generation. The infection is therefore "hereditary" in the aphid. The possibility that there is an incubation period in the insect before it can transmit the disease is not excluded. Non-infected insects that remained on blighted plants for different periods of time, from ten minutes to forty-eight hours, and were then transferred to healthy plants, caused symptoms of the disease to appear in the latter in from seventeen to twenty-four days, the incubation period being about the same in the case of those that fed fourteen, twenty-four, and forty-eight hours, but being longer in those that fed for two hours and ten minutes respectively.

The study of insect transmission has therefore shown that in curly top of the beet the insect is not a mere mechanical carrier of the infection, but is an alternate host in which the virus undergoes some change, and it has also shown that the infection in spinach blight is hereditary in the insect. These are important advances.

Transmission by the juices of infected plants has been most fully investigated in the mosaic disease of tobacco.[1] This is perhaps the most highly infectious virus disease of plants known, though it does not kill. The virus is present in all parts of the plant that have been found so far capable of separate examination—leaves, stem, roots, flowers, and seeds. In the latter it is present in the seed coats, but evidently not in the embryo, since it is not transmitted through the seed to the seedling. Direct testing of the embryo for the presence of the virus after removal of the enclosing tissues would probably not be possible without causing contamination. Even the hairs of the leaf contain it. Infection can be produced by inoculating any part of the plant, the slightest abrasion, even broken or cut leaf hairs, permitting entry. The leaf hairs of infected plants have been carefully cut with sterile scissors so as to avoid injuring the tissues below, and the scissors thus contaminated with the contents of the hairs have been used to cut the hairs of healthy plants and have caused these plants to become infected.

[1] Allard, H. A., The Mosaic Disease of Tobacco, *U.S. Dept. of Agric. Bull.*, 40, 1914, and subsequent papers in *Journ. of Agric. Res.*, v, p. 251, 1915 ; vi, p. 649, 1916 ; vii, p. 481, 1916 ; x, p. 615, 1917 ; and xiii, p. 619, 1918.

Rubbing the leaves with the fingers acts in the same way. With needle inoculations, single pricks often fail, the best results being got by multiple inoculations.

The virus does not seem to be equally active or equally concentrated in all parts of the plant; thus inoculations from the roots give a lower percentage of success than those from the leaves. "Carriers" are known, *e.g. Physalis* may be inoculated and transmit the virus by subsequent inoculation from it to other plants, but itself may show no sign of the disease. So also the grafting of an infected plant on an immune variety of *Nicotiana* makes the juice of the latter infective, though no symptoms are produced. Direct inoculation of the virus into an immune species may set up a destructive tissue rot, though no other symptoms appear and though rotting is not a symptom of mosaic in susceptible plants. Possibly immunity here is related to those cases known in the plant rusts in which varieties whose cells are too readily attacked and killed are immune merely because the parasite is unable to feed and grow in the presence of dead cells, and soon dies out. Mixing the virus with the sap of immune species of *Nicotiana* does not reduce its virulence. The virus travels slowly in the plant. It has been found to take three days to traverse a leaf and its stalk. It can be transmitted to several other plants of the same family (Solanaceæ), including tomato, petunia, *Datura*, *Hyoscyamus*, and *Capsicum*, but the divergent results obtained by different investigators in Europe and America, together with other circumstances, indicate that there are two or more distinct mosaic diseases of tobacco, just as it is clearly proved that there are several of potato. *Nicotiana viscosum* is known to have a distinct mosaic disease not communicable to tobacco, though both it and the tobacco mosaic can be transmitted to *Datura stramonium*. Transmission by insects (aphids) is common, but not all insects that feed on tobacco can carry the virus. The large green aphis of lettuce (*Macrosiphon lactucae*) will feed and multiply readily on tobacco but does not transmit mosaic, nor does the white fly or red spider. Though the fresh juice is infectious, the best inoculum of all tried is the dried leaf tissue macerated in water.

The allied potato mosaic is not so readily transmitted as the last; for instance, rubbing the leaves is not sufficient. Bean mosaic is also more refractory, as it is often difficult to get success by inoculating the juice into the tissues from a syringe or by rubbing the leaves; the best results are got in this case by using the crushed tissue of the leaf. In the cucumber mosaic,[1]

[1] Doolittle, S. P., The Mosaic Disease of Cucurbits, *U.S. Dept. of Agric. Bull.*, 879, 1920, and The Relation of Wild Host Plants to the Over-wintering of Cucurbit Mosaic, *Phytopathology*, xi, p. 47, 1921.

too, the crushed tissue is somewhat more infectious than the extracted juice, but aphids are the most consistently successful agency for inoculation. In this case the virus is present in the stem, leaves, flowers, and fruit, but is apparently absent from the roots and usually from the seed. The leaf hairs contain the virus, and it can be successfully inoculated through broken hairs, just as in tobacco. Infection through the roots and blossoms has not succeeded. Seedling plants are less readily inoculated than those that are older but still growing rapidly. After growth has reached its maximum inoculation is again less often successful. The virus travels fairly rapidly through the plant. In one case in an inoculation at the tip of the stem, the juice of a leaf at the tip was infective twelve hours sooner than that of a leaf at the base of the plant; and in another case it took only about nine hours to traverse thirty inches of stem in an upward direction. Not only are practically all the species of Cucurbitaceæ tested susceptible to this disease, but it can be transmitted to members of several other families, including Solanaceæ, Compositæ, Campanulaceæ (*Lobelia*), and Asclepiadaceæ. Besides aphids it can be transmitted by beetles of the genus *Diabrotica*.

In the mosaic disease of sugar-cane, maize, sorghum, and various other grasses,[1] juice inoculations by injecting a considerable quantity of juice into the growing point have given some successes, but far less than when insects were used. The virus extends through the plant very slowly and healthy cuttings may be obtained from the lower part of the sugar-cane for an appreciable time after the top shows symptoms of the disease.[2] Both in maize and sugar-cane, new suckers may come up from diseased plants without showing any symptoms. There is also some evidence in the mosaic disease of potato that the virus reaches the tubers rather late in their development, and that it is at least sometimes possible to harvest immature tubers from diseased plants that may be used for "seed" without transmitting the disease.

The failure in most of the virus diseases of plants of transmission by the seed is chiefly of interest as indicating that, whatever the nature of the virus may be, it does not diffuse as readily from the supports of the ovule to the embryo as the organic nutrient materials do. In the quercina disease of *Datura* transmission by the pollen occurs as well as by the female gametes, and this appears to be the only case of the sort recorded.

[1] Brandes, E. W., The Mosaic Disease of Sugar-cane and other Grasses, *U.S. Dept. of Agric. Bull.*, 829, 1919, and Mosaic Disease of Corn, *Journ. of Agric. Res.*, p. 519, 1920.

[2] Lyon, H. L., Three Major Cane Diseases, etc., *Bull. Exper. Stat. Hawaiian Sugar Plant. Assoc.*, iii, p. 1, 1921.

## Passage of the Virus within the Plant

So far the means by which the virus is conveyed from one plant to another have been outlined. The next point of interest is the consideration of the channels of carriage of the virus within the plant.

As already mentioned, practically the only gross changes of a necrotic nature, such as might result from the localised action of a parasite, that have been observed are in that part of the vascular strand, the phloem, through which elaborated nutrient material is carried. Even where no necrosis has been reported, the translocation of starch is impeded in several cases, such as peach yellows and spike disease of sandalwood, suggesting some disturbance in the phloem. Other observations tend to support the view that this is the main channel of extension within the plant. As a rule the most certain method of transmission of the disease from one plant to another is by the sucking insects, chiefly aphids, which can convey it. It has been shown in several cases that these insects feed by inserting their probosces into the phloem, usually of the finer veins ; other tissues are avoided, or tested and abandoned, until the phloem is reached. Again in the cucumber mosaic about twice as many inoculations succeed when the infective juice is pricked into the neighbourhood of the vascular bundles exposed when a leaf is torn off than when made into the stem at random. In the infectious chloroses girdling experiments have demonstrated that the virus is carried only through the bark, which in plants such as those worked with includes the phloem tissues, but not the other elements of the vascular ring. Furthermore, the symptoms after inoculation always appear first in just those parts to which the flow of the elaborated food is directed, namely in the young developing shoots and the like.

That the vascular system is in some way connected with the passage of the virus is made more probable by the frequent failure of the latter to reach the embryo. It is known that there is no vascular connection between the mother plant and the embryo, the bundles terminating either at the base of the ovule or spreading around its seed coats, but never penetrating the nucellus which surrounds the embryo-sac. Hence the latter is nourished entirely by osmosis. The embryo developing within the embryo-sac is still further removed from vascular connection with the mother plant. In the Cucurbitaceæ the nucellus is provided on the outside of its epidermis with a well-marked cuticle, and this epidermis persists in the ripe seed, though the rest of the nucellus is absorbed. The stalk end of the ovule (the chalaza) is suberified. Thus the whole of the central part of the ovule is cut off from the seed coats and stalk by cutin or suberin. The embryo also, in the spherical stage, is provided with a complete investment of cuticle over its free parts. All the evidence available in regard to infection by the virus diseases indicates strongly that they are unable to pass through cutin and probably unable to pass through suberin (*e.g.* uninjured branches or a potato tuber). Hence one would expect that the virus of cucumber mosaic would fail to be carried over to the next generation in the seed. But this is one of the diseases which is sometimes transmitted by seed. The explanation of this anomaly is perhaps to be found in the work of Longo,[1] who has shown that since the cucurbit embryo is so completely isolated by impermeable layers, an adaptation of a curious nature has been developed in which the pollen tube opens a communication between the neck of the nucellus and the embryo-sac. Possibly the same channel could serve to transmit the virus to the embryo. Other nutritional adaptations for the absorption of organic food by the embryo, haustorial organs of the most varied morphological value, are known in a number of other families, and may perhaps have some significance in the inheritance of some of the virus diseases.

On the other hand, Allard[2] has shown that considerable interruption of the vascular tissue does not appreciably increase the time taken by the virus of tobacco mosaic (which is not inherited) to pass from the leaf to the stem, and he is therefore inclined to think it passes from cell to cell by diffusion, though the fine anastomosing lateral veins may aid. Doolittle[3] thinks the latter are the more important in cucumber mosaic.

In the infectious chloroses there is evidence that, though the virus may be distributed throughout the plant, it only multiplies in the chlorotic areas. If these are removed, as by defoliation or carefully cutting out all the yellow spots on the leaves as they appear, it is possible to get the plant to form only normal green leaves ultimately. But the virus can persist in a latent form in the dormant buds of such plants, and if these buds are forced to grow, they give chlorotic shoots which reinfect the new growth of the whole plant. The persistence of the virus in the latent condition in perennial root stocks of plants like *Phytolacca* and *Physalis*, in the swollen root of the beet, and in the potato tuber, is well known.

[1] Longo, B., Osservazioni e ricerche sulla nutrizione dell' embrione vegetale, *Ann. di Bot.*, ii, p. 373, 1905.

[2] Allard, H. A., Further Studies of the Mosaic Disease of Tobacco, *Journ. Agric. Res.*, x, p. 620, 1917.

[3] Doolittle, S. P., The Mosaic Disease of Cucurbits, *U.S. Dept. of Agric. Bull.*, 879, p. 39, 1920.

## Properties of the Virus

Leaving the discussion of the means of transmission from plant to plant and the carriage of the virus within the plant, one may next consider some of the properties of the virus, which have been chiefly investigated by Allard and Chapman in the tobacco mosaic. In this case the virus can be filtered through the Chamberland, Berkefeld, and Kitasato filters without being retained, though it passes less readily through those with finer pores. Infectivity was 91 per cent. with the Chamberland, 63 per cent. with the Berkefeld normal, 47 per cent. with the Berkefeld fine, and 40 per cent. with the Kitasato, in one series of tests.[1] It is entirely checked by filtration through the Livingstone atmometer porous cup and through powdered talc $\frac{7}{8}$ inch thick. (The cucurbit mosaic virus filters through the Berkefeld, but not through the Chamberland filters tried.) The whole of the virus is carried down with the precipitate obtained by treating with 45 to 50 per cent. alcohol and with an aluminium hydroxide precipitate, without its infectivity being injured. It is quickly destroyed by alcohol of 75 to 80 per cent., formaldehyde of more than 1 to 800 destroys it in thirty-one days and 4 per cent. very quickly, copper sulphate readily destroys the infectivity of the virus under certain conditions, but mercuric chloride and carbolic acid have little effect. Heating to over 80° C. for five minutes sometimes destroys it, but it can sometimes withstand 90° C. for the same time. It is quickly killed near the boiling point. The dried leaves remain infective for very long periods, giving as much as 100 per cent. infection after three years. The bottled juice without preservative has remained highly infective for fifteen months, though it had undergone putrefaction, and the juice treated with toluol has been found infective after three years. The virus obtained from evaporated juice loses its infectivity more quickly. Dilution of the virus to 1 to 1,000 does not reduce its infectivity, and at 1 to 10,000 some infection can still be obtained, but higher dilutions generally fail. The virus of cucurbit mosaic behaves in exactly the same way in regard to dilution, but is much less resistant in other respects than that of tobacco mosaic. It is destroyed by formaldehyde, phenol, and copper sulphate in 0·5 per cent. solutions, and by mercuric chloride at a strength of 1 to 2,000. Heating above 70° C. renders it non-infectious and drying the infected tissue has also the same effect. The expressed juice is seldom infectious for more than

[1] Chapman, *loc. cit.*, p. 107.

forty-eight hours. In the bean mosaic [1] excised leaves retain their virulence for only about the same time, but the virus (which is transmitted by the seed) will survive any temperature that does not kill the seed. The virus of potato mosaic in the latent condition in the tuber requires apparently a longer time to kill by heat than the tuber itself does.[2] There are numerous scattered observations on various properties of the infective agent in several other mosaic diseases, but space does not permit of referring to them.

## Influence of the Environment

The only other point of general interest in these diseases to which I wish to refer is the influence on them of external conditions. This is sometimes so marked as to have led to controversy as to whether the whole train of symptoms noticed in certain of these diseases may not be accounted for by unfavourable environmental conditions without invoking any parasitic agency. Cases in point are the spike disease of sandalwood, which has been proved to be graft-infectious, and the pecan rosette,[3] where no transmission from one plant to another has been proved.

In several cases the air temperature has been found to have a marked influence on the incubation period and symptoms of this class of disease. In the mosaic disease of tobacco the optimum for the activity of the virus, as judged by the length of the incubation period, is 28° to 30° C. and the maximum near 36°.[4] The development of the symptoms is slowed down by lower temperatures proportionately to the growth of the plant, and no symptoms appear at temperatures that quite check growth. Above 36° tobacco continues to grow, but the new growth in infected plants shows no symptoms of disease and even previously mottled leaves tend to become normal. The virus is not destroyed, however, as the symptoms reappear when lower temperatures are again employed. In cucumber mosaic [5] infection fails when the soil and air temperatures are below 20° C. Above this, the incubation period is shortened as 30° C. is approached. In raspberry mosaic,[6] leaves put out

[1] Reddick, D., and Stewart, V. B., Transmission of the Virus of Bean Mosaic in Seed, etc., *Phytopathology*, ix, p. 445, 1919.

[2] Blodgett, F. M., The Relation of Time and Temperature to the Killing of Potatoes and Potato Mosaic Virus, *Phytopathology*, xii, p. 40, 1922.

[3] Rand, F. V., Pecan Rosette, *U.S. Dept. of Agric. Bull.*, 1038, 1922.

[4] Johnson, J., The Relation of Air Temperature to Certain Plant Diseases, *Phytopathology*, xi, p. 447, 1921.

[5] Doolittle, S. P., Influence of Temperature on the Development of Mosaic Diseases, *Phytopathology*, xi, p. 46, 1921.

[6] Rankin, W. H., and Hockey, J. F., Mosaic and Leaf Curl of the Cultivated Red Raspberry, *Canada Dept. of Agric. Divn. of Bot. Circ.*, i, N.S., 1922.

during very hot weather show no symptoms. Total suppression of potato mosaic as a result of climate has been found to occur in parts of Canada,[1] so that affected plants give a practically normal yield, though they still retain the virus in an infective condition. Thus, under certain conditions the potato may act as a " carrier " of its own mosaic. In curly top of beet the interval after feeding on a diseased plant during which the insect is not infective is shorter at high temperatures than at low.

The influence of soil and fertilisers is marked chiefly in the direction that in good soils, and especially with heavy manuring, the symptoms may be masked and good yields obtained.[2] Peach yellows, spike disease of sandalwood, and pecan rosette are amongst the diseases in which the soil factor may be of importance.

Light may also have an influence on the development of symptoms. Baur showed that the contagium of the infectious chlorosis of *Abutilon* may be destroyed by growing the plants in darkness, and Chapman that tobacco plants exposed to blue light showed little symptom of mosaic, though the virus was still present.

## General Observations

The fact that disease can be caused by a filterable virus was first demonstrated in a plant disease—tobacco mosaic. Human pathologists have, however, advanced the study of the possible causative agents beyond the stage reached by plant pathologists. Only two observers claim to have detected a possible organism in the cells of infected tissues in plants. In certain cells of necrotic areas in the pith of the maize stem and in the cells of the chlorotic parts of the leaves of maize and *Hippeastrum* Kunkel[3] has described bodies which he compares with the Negri bodies of rabies and with *Cytoryctes variolæ*. Some of his figures may perhaps remind one of certain appearances of *Rickettsia*. Palm[4] in Java has just reported the presence in the cells of tobacco plants affected with mosaic of bodies agreeing in every respect with Lipschütz's *Strongyloplasma* or the

[1] Murphy, P. A., Investigations of Potato Diseases, *Canada Dept. of Agric. Bull.*, 44, 1921.

[2] Perret, C., Sur les maladies des pommes de terres, *Ann. des Epiphyties*, vii, p. 304, 1921.

[3] Kunkel, L. O., A Possible Causative Agent for the Mosaic Disease of Corn, *Bull. Expt. Stat. Hawaiian Sugar Plant. Assoc.*, Bot. Ser. iii, p. 44, 1921, and Amœboid Bodies associated with Hippeastrum Mosaic, *Science*, N.S., lv, p. 73, 1922.

[4] Palm, B. T., De mozaiekziekte van de Tabak een Chlamydozoonose ? *Bull. Deliproefstat. te Medan-Sumatra*, xv, 10 pp., 1922 [English translation attached].

"elementarkörperchen" of v. Prowazek, and in another form with Guarnieri's bodies (*Cytoryctes*). Here, again, a resemblance to *Rickettsia* would seem to be indicated.

No systematic search for the agent in transmitting insects appears to have been made. That there is a gradation of size in the infective agent in the different filterable virus diseases of plants is evident from the filtration experiments, the cucurbit mosaic, for instance, being more easily removed by filtration than that of tobacco.

Various indications suggest that the parasite must often be closely associated with the living protoplasm of the host cells. The plant juice is not usually as highly infective as the crushed tissues, and transmission by grafting is one of the most successful methods and the only one known in several cases. There is not the slightest evidence that the infective agent can live saprophytically, and the failure to get infection through the soil in very many carefully conducted tests, though the underground parts of the plant are exposed to frequent wounding in many ways, is conclusively against a soil life. Failure to cultivate the active agent is common in the obligate plant parasites, none of the rusts (of which there are several thousands) having ever been grown apart from its host.

The localisation of active symptoms to developing parts of the plant is a remarkable feature of these diseases. Infection is followed by the appearance of symptoms (chlorosis and various other manifestations) only in the newly formed shoots and leaves. Those that have already reached their full size remain unchanged, though in many cases they are highly infective. The virus can at least live in the mature tissues, but it is apparently unable to do harm to any but developing tissues, except where it is able to cause necrosis, as in leaf roll disease of potatoes and allied diseases.

Though there is no evidence in many of these cases that the virus passes through any necessary part of its life cycle in the insect carrier, it is sometimes very noticeable that only certain species of insect can transmit it. In the tobacco mosaic some species of aphids will cause infection, but others fail, though they feed and multiply readily on tobacco; and in sugar-cane mosaic only *Aphis maydis* has been proved capable of transmitting infection, though many other sucking insects feed on cane. The case is possibly similar to that of Japanese river fever, where it would seem that the mite which ordinarily transmits the disease is not a mere mechanical carrier, but its intervention is not always necessary to secure infection, since all stages of development of the parasite can take place in man. Or we can imagine a condition similar to that obtaining in some heterœcious rusts, which can propagate indefinitely in the uredo stage. In this case the insect would correspond to the æcidial host where the latter has ceased to be essential to the fungus, as with black rust of wheat in India. The similarity to typhus fever in many points is also worthy of note.

These diseases may be hereditary, both in the plant (transmission by seed in bean mosaic and the like) and in the insect (spinach blight).

The injurious effect of these diseases varies from almost nil to total destruction : sugar-cane mosaic in Louisiana produces such slight effects, even in cases of 100 per cent. infection, that no reduction in yield of sugar has been proved, while spike disease of sandalwood trees is invariably fatal and is exterminating this valuable tree throughout a large area. The disorder is clearly a nutritional one in the first instance and the profound alterations in the enzymic activity of diseased plants have been chiefly responsible for the so-called enzymic theory of mosaic disease. In a case like the potato, where Quanjer has recently distinguished no less than four distinct diseases of the infectious mosaic type, besides true leaf roll and a second leaf roll not yet known to be infectious, it is evident that an immense amount of work is still required before the effects on the metabolism of the host can be clearly understood.

The increasing attention being paid to this class of disease by plant pathologists is not entirely the result (though in great part) of improvement in diagnosis. In certain cases there is a real extension going on, as in the sugar-cane mosaic, which has appeared recently in several important cane-growing countries. It is not suggested that any of them are of recent origin, as the facts can be sufficiently explained by the great activity of recent years in the introduction and testing of new varieties of plants from all parts of the world. Sugar-cane mosaic has been present in the Dutch East Indies for many years, and there is little doubt that it has reached the New World with eastern sugar-cane varieties introduced in considerable quantity in recent years. As a class, the diseases mentioned in this paper rank at present amongst the most destructive diseases of plants known.

# POPULAR SCIENCE

## THE SCIENTIFIC PICTURES OF JOSEPH WRIGHT

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Wright's three great scientific pictures, "The Orrery," "The Air-Pump," and "The Alchymist," accurately reflect the state of physical science in his day, and it is a very fortunate circumstance that they are now exhibited together in the Art Gallery of his native town.

Wright of Derby, as he is usually called, was born in 1734 and died in 1797, so that his working period coincides with the latter half of the eighteenth century. The physical science of the period, in contrast with that of our own times, was unspecialised and a matter of general interest among people of education. The number of educated people was, of course, smaller than in our own time, smaller too in proportion to the total population, the chief subjects of study being the classical languages and mathematics, but it was a happy feature that people with this training should nevertheless take a keen interest in the teachings of science. There seems to have been no tendency among the votaries of art to regard with antipathy the progress of science, and no tendency to decry the value of science in favour of the humanities. They were more leisurely days when the keenness of the struggle for existence and the inevitable tendency to minute specialisation, which necessarily restricts the scope of our intellectual interests, had not yet rendered it wholly unprofitable for any one man to take all knowledge for his province, but in an age when we have been not inaptly described as an unscientific people trying to live in a scientific age, one cannot help looking back with some regret to the more general interest in scientific knowledge of former times. In Joseph Wright we have a distinguished artist who was obviously an interested and careful student of contemporary science and whose knowledge of the scientific details portrayed in his pictures is surprisingly accurate.

"THE ORRERY."
"A philosopher gives that lecture on the Orrery, in which a lamp is put in the place of the sun."

"THE AIR-PUMP."
"An experiment on a Bird in the Air-pump."

'THE ALCHYMIST."
"The Alchymist in Search of the Philosopher's stone ; discovers phosphorus, and prays for the successful conclusion of his operation, as was the custom of the ancient chymical astrologers."

Taking the pictures in the order in which they were painted, we may regard "The Orrery," "The Air-Pump," and "The Alchymist" as typical of the state of development of the sciences of astronomy, physics, and chemistry respectively, in the latter half of the eighteenth century.

To "The Orrery," which was exhibited in the year 1766, the artist gave the title "a philosopher gives that lecture on the Orrery, in which a lamp is put in the place of the sun." By the term *philosopher* we are to understand a natural philosopher, *i.e.* one whose studies had embraced, besides a sufficiency of mathematics, the subject of mechanics, including statics and dynamics, astronomy and other branches of physics so far as they were then developed. With the progress of specialisation the term *natural philosophy* has fallen into disuse.

In Wright's day the science of astronomy was already firmly established on thoroughly sound foundations. Observational astronomy is, of course, one of the oldest of sciences, and eastern shepherds in distant ages, mariners in all ages, and possibly even men of the Stone Age, were far more familiar with the magnificent spectacles which the heavens present to our gaze than is the average town-bred product of a modern education.

Copernicus, in the first half of the sixteenth century, was able to show, as the result of many years of careful observation and calculation, that the earth is not the immovable centre of the universe around which the heavens revolve, as was commonly believed during the Middle Ages, but that, like the other planets, it revolves round the sun. Kepler early in the seventeenth century, by studying the valuable observations of Tycho Brahe, established laws which accurately describe the motions of the planets in elliptical orbits with the sun in one of the foci. Galileo about the same time constructed a telescope and applied it to the study of the heavens. He was richly rewarded by the discovery in succession of the difference in the appearance of a planet and a star, the moons of Jupiter, the phases of Venus, the rotation of the sun, and the mountains and valleys of the moon. We owe to the genius of Newton, in the latter half of the seventeenth century, the laws of motion and the law of gravitation, which explain why the planets move in the manner described by Kepler and thus place the science of physical astronomy on a sure basis.

The picture takes its title from the instrument portrayed. It is a contrivance for representing the positions and motions of the heavenly bodies and, generally speaking, for illustrating the facts and principles of astronomy. It has a very wide range of useful application, and by its means the leading truths of the science may be demonstrated to those who are unable seriously to study the subject. In other words, it is an instrument for popularising the study of astronomy.

Such an instrument appears to have been made for the first time early in the eighteenth century to illustrate the motion of the moon, other features being soon added. One was made for the Earl of Orrery, who played the part of patron and encouraged its use. The new instrument was therefore called by his name at the instance of Sir Richard Steele. Interest in science being general, it soon became fashionable, and evidently one must have been available for Wright's use in Derby. Many orreries were operated mechanically, but there is no trace of mechanism in the picture, and the movements were doubtless made by hand. The horizontal circle represents the plane of the ecliptic in which the earth moves, and on it are depicted the signs of the zodiac and the months of the year. The orbits of the planets were probably traced on the horizontal surface below the ecliptic. The inclined circle is the Equator, and the great circles at right angles to it meet in the Pole. These enable the position of a planet or star to be determined. Similar instruments are still made, although their popularity is a thing of the past. The figures in this picture are portraits of Wright's friends.

The position of the lamp is worthy of notice. The lamp itself is hidden by a figure in the foreground, whilst it strongly illuminates the greater part of the apparatus and the faces of the company. Its reflection is seen in the foreground.

The second picture bears the title "An Experiment on a Bird in the Air-Pump." The air-pump had been invented by Otto von Guericke, a magistrate of Magdeburg, rather more than a century previously. Von Guericke's air-pump consisted essentially of a copper globe to which a pump was attached. The means of creating a vacuum had long been desired, and the invention immediately attracted the attention of the leaders of science throughout Europe. As a result mainly of the labours of the English workers Boyle, Hook, Hawksbee, and Smeaton, the latter a contemporary of Wright, it assumed the form of the double-barrelled pump with the flat plate and glass receiver as shown in the picture. In this form it was an efficient instrument for producing what we should now regard as low vacua. Von Guericke was also the inventor of the Magdeburg hemispheres which appear in the foreground of the picture. It is said that when placed together and exhausted, two teams each of fifteen horses failed to pull them asunder. In the picture the receiver is shown mounted on a tall pillar, a quite usual feature in air-pumps of the period.

Whilst the various branches of mechanics were well developed at this period, and considerable progress had been made in the study of light, the remaining branches of physics were, as compared with their present condition, in a state of infancy. The properties of gases had, since the invention of the air-pump, formed an important subject of research. It was recognised that air played an important part in respiration and combustion, but the nature of this action was not understood, and these were the problems of outstanding importance. In order to solve the problem of respiration, a great many experiments similar to the one portrayed were made by philosophers of repute and duly reported to the Royal Society. Wright's picture is evidence that they were being repeated for the instruction of those to whom science was a matter of general interest. In these experiments a small animal or bird was placed in the receiver, which was then exhausted. Clinical observations of the convulsions and time of collapse were then made. Air was readmitted, when, happily, in most cases the patient revived, although there were regrettable occasions when a fatal result ensued. The pigeon in this case was probably none the worse for the trying experience. The girl who is shielding her eyes doubtless fears that the bird is dead, and is being assured by the man who has an arm round her shoulders that it will revive. It will be noted that the figure in the left of the foreground holds a watch in his hand, for timing the convulsions, the collapse, and the revival.

It is said that several of the figures in this picture are the same as those in "The Orrery." The lighting is effected by a candle placed behind an inverted receiver or bell-jar containing water, the candle itself being hidden.

The original "Alchymist" was exhibited in 1771, and was taken to Italy by the artist in 1773. It bears the title, "The Alchymist in Search of the Philosopher's Stone; discovers phosphorus, and prays for the successful conclusion of his operation, as was the custom of the ancient chymical astrologers."

Astrology and alchemy had their origin in very early times, and continued during the Middle Ages. As a rule the same men practised both arts. That Wright's alchemist was also an astrologer is indicated by the globe and horoscope on the right of the picture as well as by the title. The discoveries of Copernicus sounded the death-knell of astrology, though its death was lingering. Wright's period was the transition stage between alchemy and the modern science of chemistry, the twilight before the dawn.

Alchemy was a strange mixture of blind experimenting, magic, and mysticism. Lacking the guidance of sound theory, it relied on tradition and followed the will-o'-the-wisp of false analogy. Its literature was replete with wild allegories expressed in an obscure jargon which served to conceal the meaning from the uninitiated. The alchemists, nevertheless, gleaned many facts which form the groundwork of chemistry, and we owe to them many useful materials, chemical processes, and pieces of apparatus. In mediæval times many of them were able, honest, and even religious men ; some may indeed be justly regarded as the great men of their day ; but by the seventeenth century the cult had degenerated into charlatanism, and the adepts were fraudulent quacks who trafficked in the philosopher's stone, which was supposed to have the power of turning base metals into gold, and the elixir of life, which was said to cure every ill and to prolong life indefinitely, preserving perpetual youth.

In Wright's time alchemy was to a great extent discredited, but the birth of chemistry was retarded by the phlogiston theory, a false theory of combustion which regarded flame as an elementary substance. The composition of air and water, hitherto considered as elements, and the chemistry of the gases of which they consist, were being investigated by his contemporaries Black, Priestley, and Cavendish, who still expressed their results in terms of the phlogiston theory. Towards the close of the century the French chemist Lavoisier promulgated the doctrine that the gases oxygen, nitrogen, and hydrogen were elements, and that the process of combustion could be perfectly explained without assuming the existence of phlogiston. After considerable controversy his views were generally accepted ; henceforth chemistry was freed from the shackles of the phlogiston theory, and the foundations of the modern science were made secure.

The subject of the picture is the discovery of phosphorus, which was first obtained accidentally by a citizen of Hamburg named Brandt, about a century previously in the course of his search for the philosopher's stone. The details of the process were kept secret for many years, but an adequate account was published earlier in the eighteenth century. With this description Wright was obviously familiar. The materials from which the phosphorus was prepared were strongly heated in a furnace and the phosphorus distilled over into a glass receiver. The finely painted figure of the alchemist with the furnace and receiver constitutes the principal feature of the picture. The end of the retort protrudes from the furnace, and the spherical receiver which was called a balloon is luted to the retort. The balloon is nearly half filled with water and, as the phosphorus distils over, the upper part is filled with luminous vapour, whilst from the small hole in the top near the neck of the balloon the vapour rises in a luminous jet. The balloon with its luminous vapour furnishes the source of light which gives the characteristic lighting effect.

One might at first be inclined to think that the small hole and the jet of luminous vapour were the product of the artist's imagination, but reference to contemporary literature justifies these features, and shows that Wright had carefully studied the available descriptions of the process. The quotations which follow are from a work of the period, which was translated from the French at the time when Wright was at work on the picture and which he may have consulted :

" The retort ought to be well luted to a receiver of moderate size, pierced with a small hole, and half full of water. For this purpose ordinary fat lute may be bound on with strips of linen, dipped in a lute prepared with lime and whites of eggs. The hole in the furnace through which the neck of the retort passes ought to be well stopped with furnace earth. Lastly a small wall of bricks is raised between the furnace and receiver, to guard this vessel against heat as much as possible."

" The retort is to be heated by slow degrees during an hour and a half ; and then the heat is to be increased till the retort be red-hot and the phosphorus begins to pass in luminous vapour : when the retort is almost of a white red heat the phosphorus passes in drops, which fall and congeal in the water at the bottom of the receiver."

" Phosphorus is a kind of sulphur composed of a peculiar acid united with phlogiston. This matter is extremely fusible, as we have seen. It has, like sulphur, two kinds of inflammation ; one very weak, emitting a flame not powerful enough to kindle other combustible matters, but sufficient for the gradual consumption and burning of its own phlogiston ; the other is vivid, brilliant, and strong, accompanied with decrepitation, and capable of kindling instantly any combustible matter. These two flames of phosphorus are easily distinguishable during the distillation of it, when the small hole in the receiver is unstopped ; for when the vessels are not too much heated, the flame which issues through the hole is luminous in the dark, but does not kindle combustible matter ; it may be touched without danger, and it only renders the hands that touch it luminous. But when the vessels are too much heated, the flame issues with more force ; it then decrepitates, and is capable of burning any person that touches it. The flame is a sign that the heat is too strong, and therefore when it is perceived, the fire ought to be lessened."

There are also instructions for boring the hole—which was to be half a line in diameter and closed with a wooden peg—as well as for making lutes.

In the picture the furnace earth, the lute, the small hole and the luminous vapour are faithfully reproduced, and the description of the process sufficiently explains the anxiety of the alchemist at the crisis of the operation.

The group of exquisitely painted objects which complete the strongly lighted part of the picture merits careful attention. The table behind the figure of the alchemist is covered with a cloth. On it lies a piece of drapery which hangs down behind the jet, through which the pattern is seen. To the right is a horoscope inscribed with various signs among which the symbol for phlogiston may be discerned. Two closed books rest on the horoscope, and behind them stand a globe and two vases. The alchemist is represented kneeling on his left knee in an attitude of prayer, but the horoscope suggests that he had not omitted to consult the stars in order to secure an auspicious day for his experiment. Two open books complete this interesting group, one on the right leaning against the globe, the other on the left between the vases. The adjacent inkstand suggests that the latter is the manuscript record of the alchemist's experiments, whilst the others are doubtless the treatises of celebrated adepts. The inkstand with the two flasks and the clock in front of the pillar constitute a darker group of minor interest.

To the left of the furnace is a fine wicker-covered jar, and on its right is a dark alembic or still with two smaller jars, which balance the illuminated figure of the alchemist. A shovel rests against the wall of the furnace.

On the left of the picture the youth with the blowpipe and the woman with the objects on the wall behind furnish a secondary feature of interest. The group is lit by the flame of the blowpipe lamp, the lighting scheme being similar to that of the principal group, although more subdued. The blowpipe is of the earlier form then in use : the blowpipe and charcoal are accurately delineated, and the youth has interrupted his work to watch with open eyes the crisis of the alchemist's operation.

The furnace and balloon remain the same as in the original sketch which now hangs beside the picture. It indicates the care which the artist took in the composition of the picture. The same care must obviously have been taken to reproduce faithfully the apparatus of an earlier period, and the exquisite rendering of the details of the picture make it clear also that the work of painting it was a labour of love.

We may fairly conclude that Wright was an interested student of science, for which he seems to have displayed an early bias. We may also infer that there were educated people in his native town who took a keen interest in experimental science, and that the apparatus which is shown in these remarkable pictures was available in the neighbourhood.

# NOTES

## Scientific Politics.—V. The Election Analysed.

A GENERAL election does not change public opinion ; it merely registers the changes in public opinion since the last election. The actual results are rough and ready, and seem full of anomalies—split votes, candidates elected by minorities, and so on—but an analysis of the figures makes an election an instrument of precision that leaves as clear a record of the period as geological strata. And it may be added that almost every election deposits a few political fossils in the soil, and gives indications of new types emerging apparently from nowhere. The last election saw the birth of a mysterious little Coalition Labour Party, that called itself the National Democratic Party ; the flood of 1922 swept all its members out of existence. And the same flood flung up a Prohibitionist at Dundee, and left him high and dry—very " dry "—on the beach at Westminster.

These are the rarer species, and belong more or less to the category of political " sports," which seldom live long. The greater parties appear time after time with little change in essentials ; but their position in the nation is shown far more exactly by the number of votes cast than by the seats won or lost. A seat may be lost by one vote, but it may be won by a ten-thousand majority. The following notes ignore individual constituencies, and take voters in the mass.

A.—There are roughly 20,000,000 voters on the register. Deductions have to be made on account of death, illness, removals, or unavoidable absence ; also a small number of people have houses in two constituencies, and are therefore on the register in both, but they are only entitled to vote in one. The actual votes cast were a little over 14,000,000 ; add 3,000,000 in 59 uncontested constituencies, and the total poll would have been nearly 17,000,000. Consequently some 70–80 per cent. of the electorate voted, or would have done so if it had had the chance ; the percentage was higher in the towns than in the country, probably owing to difficulties of communication. The abstentions due to apathy were therefore not very many ; and the assumption that women would not trouble to vote proves, as it did in 1918, entirely unfounded. Reports from various constituencies indicate that they polled in about the same number as men.

There is, of course, no record as to the way they voted—a fact which the statistician may regret. But three deductions may be drawn from the existing evidence. (I) There were several strong women candidates, but only two women were returned, and those already Members of the last Parliament. Women are therefore not inclined to vote for women; and two or three women canvassers have more than confirmed this, by telling the writer that in their experience the average woman voter is distinctly prejudiced against the woman candidate. ("She don't know any more about politics than I do; she only wants to join a man's club, the hussy!" was one typical and surely libellous objection to an admirable female candidate.) (II) The average woman has no political traditions. If she does not follow her husband (or make her husband follow her) she plumps for the man, not the party. This probably accounts for bad candidates everywhere being beaten—a fact which every political headquarters will have to note carefully. (III) The re-emergence of temperance questions (local option, prohibition, licensing hours) is directly due to the woman's vote. Several candidates, fully primed with "health and home" matters, have admitted that "mother-and-baby speeches" fell flat at their meetings for women, but they were badly heckled by the ladies about drink restrictions. It is clear that the working-class woman hates the public-house, and likes her man to drink at home—or, better still, to add to the housekeeping money. This is obviously a permanent factor that will affect future elections. And it may eventually affect indirect taxation.

On the other hand, women have shown little apparent interest in public in the divorce laws, but most Members have been asked privately to facilitate reform in this direction. Most candidates are rather timid in this matter, partly from ignorance of the subject, partly from fear of the Church; but experience indicates that women generally resent the existing divorce law, and will disregard the Church in this matter.

B.—The voting figures (excluding uncontested seats, and universities, where the plural franchise still exists) are:

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| Conservative | 5,361,650 |
| Labour | 4,225,823 |
| Liberal | 2,570,316 |
| National Liberal | 1,548,286 |
| Independent | 343,890 |

But when a seat is uncontested, it is reasonable to assume that 60-70 per cent. of the voters will poll for the unopposed candidates. Now of uncontested seats 42 were Conservative, 7 National Liberal, 5 Liberal, and 4 Labour. If we take 60 per cent. as the minimum in each case, that adds a million to the Conservative vote; 100,000 to Labour; 120,000 to Liberal; and 168,000 to the National Liberal.

The revised figures then read:

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|---|---|
| Conservative | 6,361,650 |
| Labour | 4,325,823 |
| Liberal | 2,690,316 |
| National Liberal | 1,716,286 |
| Independent | 343,890 |

The Conservatives therefore polled one out of every three votes cast. And the interesting fact emerges that if it had not been for the split in the Liberal ranks, the Liberal poll would have been greater than that of Labour—4,406,602 against 4,325,823—while it is well known that many Liberals voted Conservative or Labour, either because there was no Liberal candidate, or no chance of getting him in. (On the whole the Radical section voted Labour, and the Whig section Conservative, so far as can be ascertained.)

C.—It is an interesting and relevant fact that none of the Liberal candidates who stood for the new Manchester programme (Liberalism with a dash of Labour) were returned. That is a sufficient answer to the reiterated suggestion of a Liberal-Labour union against the Conservatives. The plain fact is that Liberal and Labour will only unite to get the Conservative out, and even then not with enthusiasm; they will not agree on anything else. Nor can they be expected to do so: the fundamental Liberal creed is individualism with the minimum of State intervention, the Labour creed is the precise opposite. Moreover Labour, being in the ascendant at the moment, can hardly be expected to throw away any chances.

D.—The real weakness of Liberalism is not in its policy, but in the personal vendetta which reduces it to impotence. People are reasonably reluctant to vote for a party engaged in civil war and otherwise impotent. If Liberalism does not heal the breach, it will continue to lose to both Conservative and Labour, and politics will take on a class-division, which would be disastrous to the national interests, and which, moreover, does not really represent the mind of the country. If, on the other hand, Liberalism buries the Asquith-Lloyd George hatchet, it will attract many who dislike both Conservatism and Labour; and before the next election is held, it will justify the claim—which at present it could not dream of putting forward—of being the alternative Government.

The Conservative majority is sufficient, in ordinary circumstances, to last four or five years. The choice between Liberalism and Labour, when that period comes to an end with the inevitable swing of the pendulum, seems to depend mainly on the internal economy of the Liberal Party itself. Labour has profited very considerably from the Liberal dissensions of the past six years, but the figures of the election show that Liberalism is still strong in spite of the handicap it has imposed on itself, and the mere fact that it has an old historic tradition should give it an advantage in the fight it will have to wage with Labour in its future struggle for existence. Indeed, it will have to engage in a fight on both fronts—with Conservatism as well as Labour, and its situation is by no means easy. But it will probably discover that the hardest of fights is preferable to painless extinction.

**The Late Prince of Monaco (Sir Arthur Shipley, G.B.E., F.R.S.).**

We regret to record the death of Albert Honorié Charles, Prince of Monaco. The Prince belonged to the reigning House of Goyon de Matignon-Grimaldi, and amongst his other titles the following may be enumerated :

"Duc de Valentinois, Marquis des Baux, Comte de Carladès, Baron de Buis, Sire de Saint-Rémy et de Matignon, Comte de Thorigny, Baron de Saint-Lô, Baron de la Luthumière, Duc d'Estouteville, de Mazarin, de la Meillerage et de Mayenne, Prince de Château-Porcien, Comte de Ferrette, Belfort, Thann et de Rosemont, Baron d'Altkirch, Seigneur d'Isenheim, Marquis de Guiscard."

The Prince was born on November 13, 1848, son of Prince Charles III and his wife, Antoinette, Gräfin von Merode. In 1869 he married Lady Mary Douglas-Hamilton. This marriage having been annulled, he married in 1889 Alice Duchesse de Richelieu, who was, we believe, a niece of Heinrich Heine. He is succeeded by his son, Louis Honorié Charles Anton, who was born on July 12, 1870.

At an early age the Prince joined the Spanish Navy, and he remained for the rest of his life a thorough sailor, and, indeed, in external appearance he had a singular resemblance to the captain of a battleship or of an Atlantic liner. His love for the sea never left him, and he spent most of his spare time and much of his fortune in oceanographical studies. The first yacht which he devoted to practical research at sea was the *Hirondelle*, in which twenty-five years ago, 1885–6, he carried out his pioneer investigations as to the influence of the Gulf Stream upon the French coast. This he did chiefly by floats thrown out at various places to the south-west of the

THE PRINCE OF MONACO.

Azores. Later, in the same ship and also in the Azores' waters, the Prince developed many new appliances for dredging at various depths, and first began to use his submarine electrical lamp, by means of which he attracted fish into his traps suspended at varying depths. On his fourth cruise to the Azores, besides making many captures at depths ranging from 20 and 30 metres to 2,200 metres, he visited and explored some 14 lakes in the islands, of which 13 had never been investigated before, and 5 had not then been incorporated in any map. Many of the specimens dredged from the sea, as well as all the apparatus he had designed for oceanographical research, were shown in Paris in the Exhibition of 1889 in the Section of Monaco.

In 1891 the Prince made a trial trip in his new steam-yacht built for him in London. This, the first *Princess Alice*, was a three-masted schooner with auxiliary steam. The ship was especially designed for marine research, being equipped with three laboratories for zoological, oceanographical, and photographic work. It was further provided with a powerful electric searchlight of 10,000 candle-power for investigations carried on at night. From this boat soundings were made to a depth of 6,000 metres without difficulty.

In 1892 the Prince laid before the Academy of Sciences at Paris a project for establishing high and low level meteorological observations in the Atlantic Ocean on a large scale, proposing that weather stations should be established on the Azores, Madeira, the Canaries, Bermuda, and the Peak of Teneriffe ; while Monaco should act as centre for the collection and distribution of information obtained.

To these tasks the Prince brought his intimate knowledge of every technical detail connected with the sea and its investigation, and by the use of the machinery he had perfected he was able to add largely to our knowledge of the distribution of deep-sea animals. Moreover, he added many new species to the Atlantic fauna. Most of these were obtained in baited traps, a development of the lobster pot, sunk to varying depths, which we owe to the Prince's scientific zeal. In the traps many species were taken which had invariably eluded the trawl or dredge of the *Hirondelle*. Illustrations of some of these forms and of the apparatus he used, and of two of his ships, the *Hirondelle* and the *Princess Alice II*, are given in *Nature* for June 30, 1898, in an article written by the Prince giving in a condensed form the difficulties he encountered and the way he overcame them. Here he points out that the most unknown regions of the sea and the least easy to explore are the intermediate depths, between the surface and the bottom, for the animals that live therein are very active and are very shy, and they have ample space in which to escape.

Another method which he adopted for investigating the fauna in this region, which was especially successful in the case of some of the larger *Cephalopoda*, was to examine the stomachs of Cetacea which fed at these intermediate depths. The Prince tells us this new instrument gave him the most remarkable animals in his collection. One of these, *Lepidoteuthis grimaldii*, is the type of a new family. This was vomited during the dying struggles of a sperm whale, and unfortunately it had lost its head and arms. The fragment was about one yard long, and the complete body of the animal must have been at least seven feet in length. With the arms added it must have been a monster of colossal strength. Another immense cuttlefish, a *Cucioteuthis*, had arms as strong as a man's, and carried suckers furnished with claws as powerful as those of a tiger. In 1904 the Prince delivered a paper before the Royal Institution in which he again gave many fascinating examples of his investigations into the fauna of the deep sea.

In later years the Prince made many investigations in the Arctic regions, and here, as on his other journey, nothing seems to have escaped his notice. For instance, he records in 1907, when the *Princess Alice* was much hindered by quantities of ice and by fog, that the autochrome plates of the Lumière Company developed a blue veil over their surface at about latitude 69° 40′ N., which increased in intensity up to the highest point he attained, 79° N. On returning south this blue veil faded away as slowly as it had arisen.

The Prince has left a permanent memorial of his work in the Oceanographical Museums which he built and endowed both at Monaco and in Paris. The opening of the former was a memorable occasion. Representatives of many foreign states were entertained for a period extending over four days. The museum is a magnificent structure consisting of many floors. The roof, which is some eighty-seven metres above the sea level, forms a meteorological observatory. There are two magnificent halls, one of which is used for meetings and conferences, and the other is occupied by a collection of apparatus used in oceanography, and of a number of specimens and other marine treasures collected by the Prince. We venture to quote here, from the pages of *Nature*, an account of the museum written at the time of its opening by a close personal friend of the Prince, one who had made many voyages with him :

"The museum and the vessels attached to it, with their staffs and general organisation, are only one-half of the great enterprise which is entitled, 'Institut Océanographique Fondation Albert I Prince de Monaco.' Its seat is in Paris, where it possesses its own buildings and a rich endowment, both of them the gift of the Prince. It has professors of physical and biological oceanography and of the physiology of marine animals, and the lectures delivered during last year had the most numerous attendance of any in Paris. During the life of the Prince he exercises supreme authority. Both in Paris and at Monaco there is complete organisation for giving effect to his wishes, and in the event of his death, for carrying on the work without interruption, and on the lines inaugurated by himself. This continuity and permanence have been assured.

"It will be readily realised that the establishment of these two great institutions has not been accomplished without the expenditure of large sums of money and the devotion of much time and labour to it. It is almost impossible for anyone to realise the greatness of the work which is being accomplished without having been intimately connected with it, and even with this advantage the development of the conception is slow. As with all great achievements, it will take at least a generation before it is thoroughly understood and adequately appreciated.

"The museum at Monaco bears testimony at every turn to the great lines on which the Prince has himself worked, and in which his work is fundamental. Thus, in the purely hydrographical department, we see his bathymetrical chart of the world, on which all the trustworthy deep soundings are entered. This great document may be said to be the foundation-stone of oceanographical work. Another and much earlier piece of hydrographical work is the current chart of the North Atlantic, which gives the results of his laborious work on board the *Hirondelle*. By the methodical dispersion of floats, especially constructed to expose the least possible surface above water, along different lines radiating generally from the group of the Azores, by patiently awaiting their recovery, and by then combining their records, he furnished the demonstration that this portion of the ocean is practically a lake, bounded, not by land, but by the motion of its own peripheral waters, thus enclosing a roughly circular portion of the sea, part of which is generally associated with the Sargassum weed and called the Sargasso Sea. The water, thus self-confined in the warm, dry subtropical region, is exposed to powerful evaporation, and to a considerable annual variation of temperature at the surface. The combination of these two thermal factors furnishes the mechanical power by which the deeper layers of the water obtain more heat and attain a greater density in this sea than they do in any other part of the open ocean.

"In the museum, room is provided for a department of meteorology, a science which, especially as regards its application to the higher regions of the atmosphere, owes much to the participation of the Prince in its development. Until he directed his attention to it, the *ballons-sonde*, carrying their freight of valuable instruments, were very frequently lost. Now, thanks to the method of keeping the 'dead reckoning' of the balloon, developed and brought to perfection on the *Princess Alice*, if it is followed for a few minutes during its ascent, it may disappear in the clouds, and its recovery, when it descends at sea, is almost a certainty. This department of investigation has been prosecuted outside the Mediterranean, and in the Prince's cruises of the last two or three years it has been carried from the Cape Verde Islands in the heart of the tropics to the north of Spitsbergen, within five hundred miles of the Pole.

"Besides the collections of animals and the instruments for their capture and study, there is in the lower part of the museum an aquarium, remarkable for its size and the completeness of its installation. This already commands a constant flux of visitors, chiefly the curious, but it is also frequented by men of science for serious study. It is already proposed to enlarge it considerably. The story above the aquarium is divided into separate laboratories, fitted with a service of both fresh and sea water, and everything else required for chemical, physical, and biological study. In these laboratories the occupant has all that a laboratory can supply, and at any time fresh material from the sea, collected by one of the small steam tenders of the museum."

With the view of promoting his favourite study, the Prince founded in 1903, and endowed three years later, a series of lectures at the Sorbonne, and built a museum and laboratory in Paris, the "Institut Océanographique." Three Professors preside over this Institut, and lectures, which are very well attended, are given periodically on all problems connected with the sea.

The Prince had always been interested in the early history of man, and had been for many years occupied, in collaboration with Prof. Boule and the Abbé Breuil, in investigating the Grimaldi Caves near Genoa, and other sites both in Spain and France. In connection with these researches he had established "L'Institut Paléontologie Humaine" at Paris, where there is a wonderful museum and laboratory with endowed Professors to direct it and to foster research in the early origins of man.

Since the war the Prince took a leading part in international co-operation for the further exploration of the seas, and in 1919 he was appointed president of the "Commission Internationale pour l'exploration scientifique de la mer Mediterranée," and but a few months ago he was elected president both of the physical and biological sections of oceanography at the recent International Congress at Rome. His gift of tongues and unfailing courtesy made him an exceptionally able representative at all international congresses. Only last December he was elected, with another great authority on marine fauna, Prof. G. O. Sars, a Foreign Member of the Zoological Society of London.

Mention must also be made of the magnificent series of publications in which the results of the Prince's experiments have been announced to the world. Under his auspices, and at his expense, (1) the *Résultats des Campagnes Scientifiques accomplies sur son Yacht par Albert Ier Prince Souverain de Monaco* began to appear in 1889; followed by (2) the *Bulletin de l'Institut Océanographique* in 1904; and later by the *Annales de l'Institut Océanographique.* Whilst all these are well got up, the first is printed in the very best style and on the very finest paper, and are illustrated in the most artistic and lavish manner.

The Prince devoted his great ability and a large fortune to the advancement of science. He more than any other individual made the science of oceanography. This has been recognised by the conferring on him such honours as the scientific world can give. He also played on more than one occasion a real but unknown part in politics. A friend of the German Emperor, and a strong man intimately acquainted with the higher politics of France, he was, we believe, a powerful factor for peace in Europe. His love of science and his natural ability were only equalled by his innate modesty.

**Col. E. H. Grove-Hills, C.M.G., C.B.E., R.E., F.R.S., D.Sc.**

We are very sorry to have to record the unexpected death of Col. Edmund Herbert Grove-Hills, F.R.S. He was born in 1864, educated at Winchester, and joined the Royal Engineers in 1884. He was a member of the Observing Staff of the Solar Expedition to Africa (1893), Japan (1896), India (1898), and in 1914 had just reached Riga on his way to observe the solar eclipse at Kief, when, owing to the outbreak of war, he was recalled to join his regiment. He had been Assistant Instructor in Chemistry and Photography at the School of Military Engineering at Chatham in 1893–9, was appointed Deputy Assistant Adjutant-General at headquarters 1899–1905, and had retired in 1905. In 1906 he unsuccessfully contested Portsmouth in the Unionist interest. He was Secretary to the Chili Argentine Arbitration Tribunal in 1902, and received the C.M.G. for those services. In 1903 he was sent to Canada to advise the Government there on the survey of Canada ; and the Colonial Office appointed him to inspect and report on the Geodetic Survey Department in British East Africa, Uganda, Ceylon, and the Straits Settlements in 1907, and afterwards in 1908 in Southern Nigeria. In that year also he was President of the Geographical Section of the British Association. At the outbreak of war in 1914 he was appointed Assistant Chief Engineer, Eastern Command, at headquarters, where he remained until 1919, having been promoted in 1918 to the rank of Brigadier-General. He received the C.B.E. for his services during the war. He was Secretary to the Royal Institution from 1915 until his death. He served the Royal Astronomical Society as Treasurer from 1904–12, was President from 1913–15, and was reappointed Treasurer in 1922.

Dr. R. A. Sampson, F.R.S., Astronomer Royal for Scotland, has kindly sent us the following appreciation of Colonel Grove-Hill's astronomical work :

The early death of Col. E. H. Grove-Hills, F.R.S., will come as a shock to his many friends, not least to those who felt that his powers were seldom used to their full extent. That he was a man of supremely good judgment none will question. His administrative capacity will be sorely missed in scientific circles. The kindness of heart he showed in unobtrusive ways is known to many.

Born in 1864, he was a son of Herbert A. Hills, of High Head Castle, Cumberland. He was educated at Winchester and, passing through Woolwich, received a commission in the Royal Engineers in 1884, and served with that corps in varied capacities until his retirement with the rank of major. The European War found him in Russia, whither he and Prof. Fowler had carried their instruments to observe an eclipse of the sun. He succeeded in getting home, rejoined the army, and served throughout the war in the capacity of Assistant Chief Engineer of the Eastern Command, reaching the rank of brigadier-general in 1918. Few could give more to the war than he, for he lost both his sons in it. Of his official work with the army in topography, and as a member of numerous boundary commissions, others will speak. I would refer here to his contributions, too few but always valuable, to astronomy. Four times he took part in eclipse expeditions, in 1893 in West Africa, 1896 in Japan, 1898 in India, and 1914 in Russia. Actual observation was only possible in the first and third of these, and Grove-Hill's contributions were completely successful. In the Indian eclipse in particular he obtained most excellent photographs of the "flash" or chromospheric spectrum, which appears for an instant, with the Fraunhofer lines reversed from dark to bright, when the sun's disk is just obscured. Besides this aptitude for manipulation, he had an intuitively correct grasp of dynamical theory. His most important published paper, written in collaboration with Sir J. Larmor, deals with the Chandler movements of the earth's axis of rotation. Given the observed movements, what applied forces do these imply?—for they certainly do not correspond to the classical theory of "motion of a body under no forces." An analysis is made, full of suggestive views, and if the outcome is not conclusive, that is only further evidence of the intricacy of the phenomenon. But though Grove-Hills will be rated highly for his capacity as a scientific man, it is chiefly the personal side that his friends will remember. He took great interest in the affairs of the Royal Astronomical Society, served as President in 1913–15, and twice filled the office of Treasurer, carrying it, by his wise and energetic action, past the monetary crisis which has faced so many scientific societies owing to recent conditions. He was elected a Fellow of the Royal Society in 1911. From 1912 he was Honorary Director of the Durham University Observatory. He was a member of the Board of Visitors of the Royal Observatory, Greenwich. Recently he became Secretary and Vice-President of the Royal Institution, a post for which his good judgment, his varied interests and wide circle of friends peculiarly fitted him. No notice of Grove-Hills, upon the personal side, would be complete without a reference to his love for old books. Discrimination and accurate memory made him a good collector, and he had acquired volume by volume a collection of the earliest printed astronomical books which perhaps could not be matched by more than two or three public libraries in the country.

R. A. S.

**Mr. Alfred Noyes on Recent Literary Tendencies:**

This is an age of much charlatanry in science, art, creeds, and politics—and this is a country in which the goddess of truth does not often deign to attend public meetings. Mr. Alfred Noyes is therefore to be warmly commended for the sound drubbing which he administered to literary charlatanism in his address to the Royal Society of Literature, given on October 25 last. His fine new epic on the great discoveries of astronomy, *The Torch Bearers* (Blackwood), has pleased so many men of science, that they will doubtless be glad to hear part of what he had to say about the swarms of pretenders and eccentrics who are now often making literature, especially poetry, look so ridiculous in the eyes of the world. The Marquess of Crewe, K.G., Pres. R.S.L., was in the chair. Mr. Noyes said:

Some Characteristics of Modern Literature

Despite the vagueness of the title which I have given to my paper, I want to attempt a very definite and difficult task this afternoon. I believe that the time has come, in art and literature, as in every other department of life, when we must take our bearings; when we must try to discover, if possible, the direction in which we are moving, and—still more important—the direction in which we ought to be moving. We ought to make up our minds about certain fundamental principles and say definitely whether we really want or do not want some of the new ideas which the police are engaged in suppressing and many critics of art and literature encouraging. It is time, in short, to wake out of our Laodicean slumbers, and decide, definitely, whether we are on the side of development and construction, or on that of destruction and a return to barbarism. The world is suffering to-day from a lack of any profound belief on any subject. Burning convictions are out of fashion; and the ruling passion with old and young is the desire to be in the "movement," no matter where it may be leading; and still more, the fear of being thought to be "out of the movement." It is a matter for curious reflection that these people are doing precisely what they think was done only by earlier generations. They are following a convention, and forgetting (simply because their convention is a new one) that there are realities, and eternal realities; standards, and eternal standards; foundations, and everlasting foundations.

One of the results of the great enlargement of the field of human thought during the last century was the increasing tendency among modern writers to lose sight of these realities, and to lose their hold on any central and unifying principle; to treat all kinds of complex matters as if they were quite simple and, where a hundred factors were involved, to treat a problem as if it involved the consideration of only two or three. It was a century of specialisation, and each group of specialists strayed farther and farther from the common intellectual centre where they could once all meet. The old completeness of view, the white light of vision in which men so different as Shakespeare, Milton, and Wordsworth could see the essential unity of this complex world; man as a soul and a body; life and death as a march to immortality, and the universe as a miracle with a single meaning; all that white light of vision has been broken up into a thousand prismatic and shifting reflections. We are in danger of losing the white light, not because it is no longer there, but because the age has grown too vast for us to re-combine its multicoloured rays. Analysis has gone so far, specialisation has gone so far, decentralisation (or, in the most exact meaning of the word, eccentricity) has gone so far that we are in danger of intellectual disintegration. It is time to make some synthesis, or we shall find that art and letters are lost in a world without meaning. There are signs of it already on every side. On every side the same fight is being waged in art and letters as is being waged politically in Russia, a fight not between old fogeyism and bright young rebellion, but an abnormal struggle between sanity and downright insanity; between the constructive forces that move by law, and the destructive forces that, consciously or unconsciously, aim at destroying real values, at obliterating all the finer shades and tones in language and in thought, and at exalting incompetence.

There is an enormous difference between some of the destructive movements of to-day and the progressive revolutions of the past. Up till about thirty years ago revolutions in art and letters had a way of adding something of value to what we already possessed. The new revolutionists merely take away. They say to the painter: It is unnecessary for you to know how to draw. (The Bolshevistic value of that statement, of course, can be estimated by the multitude that it admits into the fold.)

In some of our modern music, men who are by no means reactionary or even conservative tell us that it is quite impossible to know whether members of the orchestra are playing anything even approximating to the notes of the composer; and that one can judge the rightness of the rendering only by the degrees of hideousness in the general chaotic din. If it sounds like a lunatic asylum under the influence of drink, it is probably an accurate interpretation of the work.

In poetry, your revolutionist invents no new metrical forms—that would involve a difficulty, and the search among these people is always for the easier way. He says, simply, you should abandon metrical form altogether, and he believes apparently that the regularly recurrent rhythms of the tides, the stars, the human heart, and of almost every true poet from Homer to the present day, were an invention of Queen Victoria. His own contribution is what he calls "free verse," and as a brilliant writer said recently, "you might as well call sleeping in a ditch 'free architecture.'" If it were not too frivolous for this occasion I should very much like to read to this audience some of the work which is being published in school and college textbooks, and to give you also some extemporaneous and deliberate nonsense verses. I think I could defy anyone here to say with certainty which was the educational work. But the important thing is that the whole movement is backward from the highly differentiated to the indifferent homogeneousness of the lifeless.

But there is a more serious aspect of the matter than this. All over the English-speaking world this hunt for the easier way in technique has been accompanied by a lowering of the standards in every direction. The quality of the thought and the emotion has been incredibly cheapened, and the absence of any fixed and central principles has led to an appalling lack of discrimination. Literary judgments have become purely arbitrary. They depend on the coterie to which you belong, and they have no relation to real values. An almost malignant desire to depreciate the writers of a former generation who, like Tennyson in his landscape work, made technical rivalry difficult, was accompanied by obvious and amazing ignorance with regard to the quality of his thought in his greatest work and its relation to the thought of his own age. The work of this great poet was spoken of again and again with the contempt of complete ignorance, and occasionally of malicious perversity. Even his morality was impugned as unworthy of the young generation who were—quite ridiculously—said to be in revolt against it; and at the same time, in the columns of English journals, something happened which is quite without precedent in the history of any civilised people. I would ask you to weigh what I am saying, for I have thought about this matter and weighed every word that I am submitting to you now. I have the documentary evidence here to prove what I am about to assert, and I think the time has come for some plain speaking.

A book was recently published. In the current number of the *Quarterly Review* there is a review—an exceedingly able review—of this work, which I say, without hesitation, and without the slightest fear that anyone here who has seen it will disagree with me, is the foulest that has ever found its way into print. Much of it is obscure, through sheer disorder of the syntax. But there is no foulness conceivable to the mind of madman or ape that has not been poured into its imbecile pages. It has been suppressed by the police, and is being smuggled into this country from Paris at five guineas a copy. My attention was first called to it by a column and a half in a leading newspaper, where it was said to be eagerly awaited by select literary circles. The writer said that its very obscenity was somehow beautiful and "if this is not high art, what is?" A weekly journal followed with eight columns, in which the book was compared with Goethe's *Faust*. A leading novelist said that Mr. Joyce, the author, had only just missed being the most superb novelist of all time and proclaimed him to be a "genius." Writer after writer took up the word, until Joyce and genius seemed to be almost synonymous; and even those who shrank from this book acclaimed an earlier work by the same author as that of a genius, quite unmistakably. The *Quarterly Review* is fully justified in printing its exposure of the critics who praised this insane product; but even the *Quarterly* is unable to tell the whole truth about it. The technical quality of the writing is beneath contempt; and large sections of the book are simply unspeakably degraded. No word or thought conceivable in the gutters of Dublin or the New York Bowery is omitted, and the foulest references are made to real persons in this country, attributing vile diseases to them, amongst other equally foul suggestions. There is no criminal court in this country which would not brand the book as inexpressibly degraded; and yet, only last night, in a leading newspaper, I see James Joyce referred to as one of our masters. Weighing every word, I say that, whether we know it or not, this is nothing less than a national disgrace; a disgusting blot upon our national heritage; and it is all the more disgusting in that it took place at a time when some of the noblest work of the last century—work with human faults, but—as in the case of Tennyson—work that may out-live England as Virgil has out-lived Rome—work of this quality was being depreciated and treated with a silly and ignorant contempt. One critic, in a leading journal recently, said "we resent" the fine defence of Tennyson recently made by Dean Inge. I have not noticed any resentment of this far more serious matter which absolutely confirms Dean Inge in his main contention; for James Joyce in more than one passage echoes the fatuous depreciation of Tennyson.

I have cited the extreme case of this book, because it is a complete reduction to absurdity of what I have called the literary Bolshevism of the hour. The book itself is utterly worthless and beneath consideration. It can do little harm, because the police are, on the whole, circumventing our pseudointellectuals ; and it is too corrupt to have more than a brief and surreptitious existence. But what concerns us all and most urgently demands consideration is the appalling fact that our metropolitan criticism should have treated the works of Mr. Joyce seriously as works of genius simultaneously with the condemnation of some of our noblest literature. There is some ground for believing—as the *Quarterly Review* points out—that the book is the particularly unclean joke of a man in the last stage of physical and mental decay. A leading French critic has said : "With this book Ireland makes a sensational re-entry into the high literature of Europe." And many of those metropolitan journals which are responsible for the formation of opinion in this country and allow their literary columns to advocate what they editorially condemn, accepted the statement with the characteristic respect which these literary rebels against authority will pay to every authority on earth except that of truth and right. The result is deadly to literature, for it confuses all real values in the minds of the new generation. It is not the young ; it is not the new generation in revolt that is responsible for this confusion. The confusion is produced by the cynical, sophisticated, middle-aged or elderly pseudo-intellectual, sitting in London, and stimulating his jaded senses with the abnormal and the corrupt. They tell the young that these things are the hall-mark of genius, and the young are bewildered.

Genius ! What do these men know of genius ?—the clear water of the spring at the door, the water stirred by the wing of the angel, the spirit moving where it listeth, and speaking, not through the lips of those whom the sophisticated would choose, but through the lips of the child, and the lover, and the poet. I open the pages of one of the poets whom they delight to dishonour, as having no word for our own time, and I read :

"The year's at the Spring,
The day's at the Morn,
Morning's at seven,
The hill-side's dew-pearled,
The lark's on the wing,
The snail's on the thorn.
God's in His heaven,
All's right with the world."

That is genius ! The power, in eight lines, to reintegrate a disordered world, by relating all its scattered and fragmentary tones to the central and eternal harmony.

That basis of the universe in an ultimate harmony is the first postulate of all thought, all science, all art, all literature. Without it there is nothing left to us that has the slightest meaning. And, indeed, a large part of our modern literature does seem to have reached that final stage of negation. It has reduced the world to dust and ashes and left it there. It has turned from the world in its completeness ; turned from the world that contains love and faith, and insisted on pointing us to the dust and ashes in which it says these things end. In other words, it has turned from the things which we *do* know about the greatness of human life, those great factors which can only be referred to something greater than themselves, some divine power at the heart of the universe, and has declared that all these things are illusion ; while, in the name of realism, it has occupied itself with the dust of which we know nothing, except that, under the scrutiny of science, it does indeed become an insubstantial pageant.

Some of the most notable figures in contemporary literature have been telling us or basing all their work on the assumption that the world is an accident ; and it has been made one of the tests of a man's power in art and literature that he should be able to state a negative and despairing philosophy in a new and startling way, without the slightest regard to its truth.

For such writers as these, the secret of great poetry, the poetry in which Matthew Arnold could affirm that our race would come to find a surer and surer stay, would seem to be lost. And what is that secret? It is simply this—that all great poetry, all great art, brings us into communion with the central harmony of the Universe.

The business of art is to take the isolated incident and relate it to the whole; to set the temporal fact in relation to the eternal. Poetry is the strongest part of our religion to-day, because, in the very simplest and noblest sense, poetry is religion.

The literature of the world to-day reflects as a matter of course the world's confusion. It can be said with perfect truth that never in the history of the world was there a time so fraught with danger to everything that makes life worth living, or civilisation worth defending; and yet never was there a time of such immense possibilities and hope. Neither the peril nor the hope can be exaggerated; and perhaps the peril is the price that we have to pay for so large a prospect.

The field of endeavour is so wide, that it is, perhaps, more than ever necessary at this moment to take a bird's-eye view of the whole field. The creators of our new literature must certainly be men who have a clearer consciousness of their aims and the direction in which they are going than was necessary in less chaotic times. To use a word that has been worked to death, they will have to be "constructive."

It is only in time of rigid order that the destructive mind is really useful, and even then it is only useful as a means to an end, the construction of something better. The destructive mind can only exist when it is in a very small minority. As soon as it is in a majority, the over-civilisation by which it is produced comes to an end. At the present moment the destructive mind in literature is popular, fashionable. In fact, the whole ground has shifted under our feet during the last ten years; and, unless we realise that a revision of values is necessary, there will be nothing but chaos in the literary criticism of the next few years.

We want all the new ideas, and especially all the new achievements, that the new age can give us; but one surely can hardly be regarded as a reactionary if one asserts that the great new railway station at Charing Cross will not be built any the more quickly if we devote our energies to the destruction of Westminster Abbey.

We talk of giving the new generation its opportunity, and our cynics are laying upon its shoulders the heaviest and dreariest burden that the young have ever been called upon to bear. We are telling them that dust ends all, and they are not always able to summon up that vast cloud of witness which in all ages has declared the contrary. We are dinning into their ears that there is no knowledge or device in the past that can help them; and I know of nothing sadder than the sight of the young trying to conceal the intellectual wounds that our elderly cynics have inflicted upon them. It is not one young man in ten thousand who will "revolt" against the greatest work of Browning, Tennyson, or Wordsworth.

The quietness and sadness of many of the more thoughtful young to-day arises from that bitterest and most desolate feeling of the human heart—"They have taken away my Master, and I know not where they have laid Him."

## The New Poetry:

It is really time that a memorial of protest be sent to the editors of many of our daily and weekly periodicals against the monstrous matter which they are sometimes now inserting in their columns under the name of "The New Poetry." Here is a characteristic example, said to be by an American "poet":

"I
Am in the Grip
Of a strange
Urge.
Oh Urge what do you
Represent ?
Why are you ?
Why am I ?
God knows !"

The scribbler, who has evidently nothing to say and does not know how to say even that, while he is so ignorant as to spell the vocative exclamation wrongly, is clearly only attempting to stand on his head in order to attract attention. But what are we to say of the literary gentlemen, the reviewers and dilettanti, who praise such performances as the product of a great new age of poetry ? Fortunately there are signs of rebellion ; and attention should be drawn to an amusing parody of this new school, called *Gorgeous Poetry*, 1911–20 (Philip Allan), by J. B. M. The witty author asks : "Who are they whom we are joining ? . . . They say, for the most part, nothing, but they say it repeatedly. . . . They eat their way into periodicals, like strange insects. They salute each other in the market place. Some, no doubt, have their tongues in their cheeks But most of them are sad with seriousness, and move in a gloom, unhappy and misunderstood. Others, more fortunate, are acclaimed." Here are two stanzas of one of these parodies, exactly "true to type"—note the reminiscence of Tennyson's "Break, break, break."

"Flocks of thoughts
Scramble over
The cornices
Of my mountainous mind.

"Flocks, flocks, flocks
At the foot of my bed I see,
But the undying ego
Knows nothing of all this."

### Anti-Science.

On November 24 the University of London Union Society held a debate as to whether "The Advance of Science is Detrimental to Human Happiness," and no less than 43 out of 125 voted in favour of this ridiculous motion. Of course most of the people attending were young people who probably had little or no experience in the world, and certainly none of countries in which there is no science. Science began with the first fur jacket, the first bow and arrow, and the first wigwam, and will go on until the world's incompetents succeed in subverting civilisation—which is not at all unlikely to happen. It is melancholy to reflect that this country pays something like one hundred million pounds a year in educating people to such a standard as was reached by the minority on this occasion.

### Notes and News.

H.M. the King has approved of the award of the Royal medals of the Royal Society to Mr. C. T. R. Wilson for his work on condensation nuclei, and to Mr. J. Barcroft for his researches in physiology. The President and

Council of the Society have also made the following awards: Copley medal to Sir Ernest Rutherford; the Rumford medal to Prof. P. Zeeman, for his work in optics; the Davy medal to Prof. J. F. Thorpe, for his researches in organic chemistry; the Darwin medal to Prof. R. C. Punnett, for his work on genetics; the Buchanan medal to Sir David Bruce, for his discoveries in tropical medicine; the Sylvester medal to Prof. T. Levi-Civita, for his researches in geometry and mechanics; the Hughes medal to Dr. F. W. Aston, for his work on isotopes.

The Royal Swedish Academy of Sciences, Stockholm, announces the award of the following Nobel prizes: Physics, 1921, Prof. Albert Einstein; 1922, Prof. N. Bohr, chemistry; 1921, Prof. F. Soddy, for his work on radio-activity and isotopes; 1922, Dr. F. W. Aston.

Sir Charles Sherrington has been awarded the Anders Retzius gold medal of the Swedish Medical Society. This medal is awarded every five years to distinguished workers in anatomy or physiology.

Prof. E. T. Whittaker has been elected a foreign member of the Reale Accademia dei Lincei.

Prof. F. O. Bower has been elected President of the Royal Society of Edinburgh for the year 1922–3.

The death of the following well-known men of science has been announced during the past quarter: Dr. A. Crum Brown, Emeritus Professor of Chemistry, Edinburgh University; Prof. T. Godlewski, Rector of the Technical High School, Lemberg, Poland, well known for his work on radio-activity; Col. E. G. Grove-Hills, secretary of the Royal Institution and formerly head of the Topographical Department of the War Office; Gisbert Kapp, Professor of Electrical Engineering, University of Birmingham; Dr. W. Kellner, late Chemist to the War Department (Woolwich); Dr. C. G. Knott, Reader in Applied Mathematics, University of Edinburgh; Prof. J. P. Kuenen, of the University of Leyden; Dr. David Sharp, entomologist; Dr. Alexander Smith, formerly Professor of Chemistry at the University of Chicago and at Columbia University; Charles Michie Smith, astronomer; Dr. T. Takamine, biochemist; Prof. F. T. Trouton, Emeritus Professor of Physics, University College, London; W. H. Wesley, assistant secretary of the Royal Astronomical Society.

Prof. F. T. Trouton, F.R.S., who was one of FitzGerald's pupils at Trinity College, Dublin, died at Downe at the age of 59. He had a brilliant career at Trinity College, subsequently becoming FitzGerald's assistant. In 1902 he became Quain Professor of Physics, University College, London. He seems to have been never very strong, and in 1912 was attacked by a severe illness which prevented him from attending the British Association in Australia, 1914. He lost two sons in the war, and was himself a complete invalid in later years of his life. Like so many Trinity College men, he had great charm and sincerity and a fund of Irish wit. Had he been spared from illness so early in his life, there seems little doubt that his career would have been even more distinguished.

Among the notable bequests and donations to scientific institutions during the quarter were about £90,000 from the late Mr. A. M. Shield to the Cambridge Medical School; 1,000,000 francs each to the Paris Academy of Sciences and the Academy of Medicine from the late Prince of Monaco, the income to be given every two years as a prize under conditions decided from time to time by the Academy concerned; and over 840,000 francs from Prof. M. Jules Tissot, of the Paris Museum of Natural History, to endow the chair of physiology.

Lord Askwith has accepted the invitation of the Council of the British Science Guild to succeed Lord Montagu of Beaulieu as President.

Mr. F. E. Smith succeeds Prof. H. H. Turner as one of the general secretaries of the British Association. The Association has accepted an invitation to meet in Toronto in 1924, and it is announced that $50,000 will be granted to defray the expenses of visiting members and the costs of the meeting.

It is stated that the Irish Provisional Government has closed the Royal College of Science, Dublin, and put the building to military use. The students have been instructed to attend classes at the National University.

Capt. George Paget Thomson, who was recently appointed to succeed Prof. C. Niven as Professor of Natural Philosophy in the University of Aberdeen, is the only son of Sir J. J. Thomson. He was lecturer in mathematics at Corpus Christi College, Cambridge.

The eleventh International Physiological Congress will be held in Edinburgh from July 23 to 27, 1923, Sir Edward Sharpey Schafer being President. Those who desire to be enrolled as members are requested to send their names, addresses, and subscriptions (25*s.*) to the Department of Physiology, University of Edinburgh, when particulars of hotels, lodgings, etc., and all other necessary information will be sent to them.

The Dutch Zoological Society held its fiftieth anniversary at Amsterdam on September 24, at which Prof. J. F. Van Bemmelen, of the University of Gröningen, delivered an interesting address on the history of the Society.

Both *Saccocirius* and *Protodrilus* have now been taken by Dr. J. H. Orton in several places along the south coast of England. Dr. Orton points out that these archiannelides are always found in association with the planarian Gunda.

Dr. Orton has been working on the sex life of the common oyster. He has been able to show that in a very short time the male oyster may change to a female. Apparently the temperature of the water is one of the factors concerned, for in cold weather there is a production of sperms rather than eggs. The whole matter must be viewed in the light of hermaphroditism in a mollusca generally.

It is such facts that have been obtained by Dr. Orton which show that the sex chromosome hypothesis alone does not suffice to explain all the facts of sex determination. Quite recently Prof. Gatenby, in conjunction with Mr. Subba Rau, has reinvestigated the questions surrounding the structure known as Bidder's Organ. In this material also evidence was adduced which showed that the sex of amphibia was extremely unstable.

Prof. H. H. Dixon, of Dublin University, in his presidential address to Section K of the British Association at Hull on September 7, discussed the question of the transport of organic substances in plants. He rules out the participation of the bast in the longitudinal transport of organic substances in plants. He believes that the transport of the organic substances needed in the distal growing regions is effected through the tracheæ of the wood. The substances travel dissolved in the water, filling these channels, which is moved by transpiration, expansion of the growing cells, or root pressure.

We are glad to see that Sir Ronald Ross is bringing out through Mr. John Murray a new work entitled *The Great Malaria Problem and its Solution*. This book will serve as a guide for those who wish to read of the discoveries which have been made in relation to malaria and mosquitoes.

What is probably a very important discovery has been made by Prof. Drummond and Mr. Watson in connection with vitamin A in fats. The well-known reaction is given by liver oils in the production of a purple coloration when the oil is dissolved in an organic solvent and a drop of sulphuric acid added ; this seems to have some connection with the presence of vitamin A. Experiments which are known to destroy vitamin A also have the effect of preventing the oils from giving this colour reaction. This work is still in an unformed state, but further researches on it will be awaited with interest. We take this opportunity of congratulating the senior author on his promotion to a professorship in London University.

In the Zoological Laboratory, Trinity College, Dublin, a special department has been created for the study of diseases of bees. The diagnosis and field work is in the hands of Lieut.-Col. C. Samman, and investigation on the embryology and pathology is being undertaken by Prof. J. Brontë Gatenby.

In the presidential address of E. J. Allen to Section D of the British Association at Hull, mention is made of an extraordinary fact with regard to synthetic sea-water. Such sea-water will not allow the growth of various low marine organisms unless a small quantity of natural sea-water is added. The exact significance of this is difficult to ascertain, but in it there may be the nucleus of a great discovery.

In another part of this journal we have printed a review of Prof. Johnstone's book entitled *The Mechanism of Life*. It is a book something apart from the course of ordinary zoology, and our review has been made by Mr. R. A. P. Rogers, a mathematician and philosopher (page 499).

We have received from the Director of the Zoological Survey of India a further instalment of the capital *Records and Memoirs of the Indian Museum*. There is an interesting paper on the "Fauna of an Island in the Chilka Lake." There are also a number of important entomological papers; Dr. Annandale continues his contributions on the fresh-water molluscs of the Indian Empire. In another volume of the *Records*, Dr. Stanley Kemp has given a large number of notes on the Crustacea Decapoda in the Indian Museum, while Seymour Sewell and Annandale have published a paper on the hydrography and fauna of Rambha Bay, which forms the south-western extremity of Chilka lake.

In the *Ohio Journal of Science* Stephen R. Williams, of the Department of Zoology, Miami University, gives some interesting details of the unhindered growth of the incisor teeth of the Woodchuck.

The left lower incisor grew in a regular curve up to the eye, ploughed through the eye, and blinded it. It can be seen that the direction of growth was changed into a section of a larger circle as the end of the tooth slid backward along the frontal bone. The continuous curving growth of the tooth was not to be resisted by bone, however, and so the point of the tooth perforated the skull a short distance behind the eye socket, and is said by the preparator to have penetrated the brain also.

This perforation of the skull and brain must have been some time before the animal's death, for the last visible part of the tooth is sheathed with a connective-tissue envelope probably continuous with the periosteum of the skull through which the tooth passed. How far into the brain the tooth penetrated can never be determined. The whole socket of the eye was a suppurating mass when the animal was killed.

How did the animal get any nourishment at all? The bodies of the upper and lower incisors fixed side by side seem to make entrance of food into the mouth absolutely impossible. At all events, it is quite certain that the animal was unable to hibernate because it had not accumulated enough fat for that purpose.

Among the *Smithsonian Miscellaneous Collections*, vol. vii, Alexander Wetmore has published a paper on the body temperature of birds. As in the case of most mammals, the temperature of the female bird was found to be slightly higher than that of the male of the same species. This applied throughout with only few exceptions—for example, in the case of the great blue heron, the male was one degree higher in temperature. Both the mammals and the birds possess a heat-regulating mechanism for keeping the body temperature constant. The author does not seem to have entered into the physiological basis of this mechanism, though even in the case of the mammals a knowledge of this subject is far from being on a satisfactory basis.

With reference to the diurnal rhythm of body temperature which has been observed in all homoiothermal animals, Wetmore supported the work of previous observers, which had shown that the temperature of birds is highest during the day and lowest at night, the exception being nocturnal birds, such as owls, where this rhythm is reversed.

In *Nature*, E. W. Gudger endeavours to give an explanation of the miraculous draught of fishes in the Gospel according to St. John. The twenty-first chapter of this gospel says: " Simon Peter saith unto them, I go a fishing. They say unto him, We also go with thee. They went forth, and entered into a ship immediately; and that night they caught nothing. But when the morning was now come, Jesus stood on the shore. Then Jesus saith unto them, Children, have ye any meat? They answered Him, No. And He said unto them, Cast the net on the right side of the ship, and ye shall find. They cast therefore, and now they were not able to draw it for the multitude of fishes."

It appears from the accounts of various observers that the fishes in the Sea of Galilee, which are mainly perch-like in form and affinities, are in the habit of going about in shoals even over an acre in extent, so closely packed that it is impossible for them to move freely. Dr. Gudger believes that Jesus was on high ground overlooking the lake, and from this position was able to point out a school to the fishermen, who cast their nets, and were able to draw them up full to the breaking point.

Theophilus S. Painter, in a recent volume of the *Anatomical Records*, gives a short account of his work on human spermatogenesis. As is well known, Weiman, in the *American Journal of Anatomy*, 1917, believed that he had shown that the number of chromosomes in man was 24. Weiman showed that they were two heterotypic chromosomes, the usual XY complex; in the maturation divisions the X and the Y were separated out, and sex determination in man was brought about by an XY chromosome mechanism. According to Painter, the number of chromosomes in man is 48, and not 24, as previously claimed by Weiman. It is evident that in the case of Weiman's material either unsuitable or delayed fixation has produced a fusing of the chromosome pairs. It may be taken as established that the number of chromosomes in man is 48, and that in all probability the sex is determined during fertilisation, and at no period either before or after fertilisation, as has been claimed by some workers.

Nevertheless, we think it would be injudicious for anyone to say that the sex chromosome hypothesis suffices to explain all the facts in sex determination and sex change.

An interesting pamphlet, " Research Work in Progress," has just been issued by the British Non-ferrous Metals Research Association, of 71 Temple Row, Birmingham. The investigations in hand cover many important problems of the Copper, Brass, Aluminium, Nickel, and Lead industries, as well as subjects of importance to all users of such metals. The support given to this association by the leading firms seems to be most encouraging, but the field covered is very wide, and many of these researches, such as those on the improvement of brass, on metal polishing, and on soldering, should attract the attention and support of many other sections of industry. The user is apt at first sight to overlook the fact that he is even more interested in the improvement of quality of his raw material than the manufacturer of the metal. In the case of failure, however, it is the user who always bears the greater loss, since he sacrifices all the time and workmanship which has been expended on the article being manufactured.

The Bureau of Information of the association also seems to be doing excellent work in distributing to members reports of the results of the experimental researches and acting as a live intelligence service collecting and distributing information likely to be of use to the industry and from the far corners of the world.

Finally, some indication is given of the further work which the Council hope to take up when additional financial support is forthcoming, which includes problems of importance to the electrical industries, to die casters, and to the tinplate trade.

The Department of Scientific and Industrial Research has reissued in booklet form (H.M. Stationery Office, price 3*d.*) the reports of the Fuel Research Board on Gas Standards, presumably for the purpose of combating the recent misdirected newspaper agitation against the introduction of the therm. It appears that under the original Act tests on the calorific value of a gas supply could only be taken officially after due notice of the day and hour at which the test was to be made have been given to the company concerned, and the Board states that they " have had before them clear evidence in certain cases that only during the brief period of the prearranged test was the gas up to the required standard and that at all other times it was much below that standard." The recommendations made to prevent such cases were as follows : (1) That each gas company should be free to choose the calorific value best suited to its particular local conditions ; (2) that this value must be declared and adhered to ; (3) that the company must adjust the appliances of its consumers, free of charge, to burn the gas supplied efficiently ; (4) that tests should be made at times unknown to the company and preferably that they should be made continuously with the Simmance Recorder, the records from that instrument being exposed for public inspection. It is clear that these recommendations do not necessarily involve the use of the therm, but excellent reasons are given for its introduction (*e.g.*, that only by expressing cost in terms of some such unit would the charges of different corporations be directly comparable). Obviously the use of the new unit cannot of itself have increased the cost of gas, as it is alleged to have done, and the pamphlet issued by the department gives no hint as to the real reason—the price which the companies have been permitted to exact per therm. This leads us to the serious defect in an otherwise excellent and opportune publication—it gives us the recommendations of the Board, but tells us nothing at all about the form in which they were incorporated in the new Gas Act.

We have received from the National Research Council of the United States, *Bulletin No.* 18, a valuable report on Modern Theories of Magnetism, and *Circulars* 24, 30, 34, and 37 dealing respectively with the Grignard Reaction (including a complete bibliography with 1,485 references), Contact Catalyses (the report of a committee of which Wilder D. Bancroft was chairman), the *Indexing of Scientific Articles* (by Gordon S. Fulcher), and Recent Geographical Work in Europe. This contains an account of the activities to the geographical associations and the geographical departments of all the countries in Europe. It appears that this subject forms part of the curriculum of all the French and German universities (16 and 23 in number), but only in 16 out of the 18 English ones. Geographical research appears to be best cultivated in Germany, and the twentieth meeting of German geographers was held in Leipzig in May 1921, after a lapse of seven instead of the usual two years. At this meeting a resolution was passed calling on all German map publishers to show the territories lost by Germany, including her former colonies on all maps of the relevant areas, including school maps. An unfortunate resolution showing that, even in scientific circles, there remains an unhappy intention to foster and aggravate the wounds caused by the war with an ultimate object which is obvious enough.

Besides the rapid issue of these valuable Circulars and Bulletins the National Research Council has just instituted a Research Information Bureau to serve as a clearing house for all kinds of scientific knowledge both pure and applied. On receipt of an inquiry the Bureau is prepared either to supply references to places where the required information may be found, or actually to abstract this information and supply it properly arranged to the inquirer. Specimen queries are given in the pamphlet relating to the Bureau, and from them it is clear that the ground it is prepared to cover is not limited to the collection of facts, but extends to such things as the location of foreign patents and advice concerning the availability of research funds. The Bureau is managed by an influential executive council and makes no charge for its services except in cases where special search has to be made. With a capable and energetic staff it is obvious that a service of this kind might give most valuable help to everyone engaged in scientific work, and one cannot help envying the country possessing it.

The Fourth Report of the British Association Committee on Colloid Chemistry and its General and Industrial Applications has now been published by the Department of Scientific and Industrial Research (pp. 382, paper covers, H.M. Stationery Office, price 5*s*. 6*d*. net). It contains a number of academic and technical papers of great value and interest. Among them are two most important papers by Mr. E. Edser, the well-known writer of physics textbooks. The first deals with the physical properties of liquids, and contains an extension of Laplace's theory of capillarity. Assuming that two molecules attract each other with a force varying as the inverse *n*th power of their distance apart, it is shown that, for liquids to possess cohesion, *n* must be greater than 4, and that, for surface tension to exist, it must be greater than 5. Substituting data obtained experimentally in the theoretical equations it is found that, for all liquids except mercury (including the liquefied "permanent" gases), *n* is equal to 8. The evidence in favour of this inverse eighth power law is very strong, and it is not improbable that the final solution to the hundred-year-old problem of the precise law of molecular attraction has at last been attained. In the course of his arguments Edser establishes a number of interesting formulæ, *e.g.* that the surface tension $s$ of a liquid at a temperature T°K is given by $\sqrt{s} = A(\rho - \rho')(1 - \gamma T^{\frac{1}{2}})$ where $\rho$ and $\rho'$ are the densities of the liquid and its vapour, and A and $\gamma$ constants, the latter approximately equal to $\frac{1}{2}T^{-\frac{1}{2}}$. He also provides a theoretical basis for Trouton's Latent Heat rule, Walden's rule, and the formula of Ëotvos. Among the numerical calculations given by the author is one which gives a surprising result for the rate of escape and return of the molecules of a liquid in equilibrium with its vapour. Thus for benzene at 20° C. the number of molecules returning to the surface per second is sufficient to renew the top layer of molecules 35,000,000 times during that period! The second paper is directly concerned with the physical aspects of the Flotation process for the concentration of minerals, and contains a discussion of such matters as contact angles, flocculation, and frothing. Among the other contents of the report are papers on "Membrane Equilibria," by W. E. Garner; "Lubrication," W. B. Hardy; and "Disperse Systems in Gases," by W. E. Gibbs, of the Salt Union Co., Ltd., the latter containing a comprehensive and most interesting account of our knowledge of vapour, dust, and smoke clouds. The report appears to us to be one of the most important documents compiled by a B.A. Committee, and the Department of Scientific and Industrial Research is to be congratulated on having provided the financial help which was essential for its publication.

Inquiries having been received regarding the Nobel Medical Prize, we have made inquiries and find that it was not distributed at all for the years 1915, 1916, 1917, 1918, 1921, and for this year.

# CORRESPONDENCE

To the Editor of "Science Progress"

## THE MENTAL ABILITY OF THE QUAKERS

From Edward Watkins, Clerk to the Fritchley (England) General Meeting of Friends

Respected Friend,—The articles which have appeared on this subject seem to miss the plain facts of the case, so far as mental ability means business ability or business success. There is no need to look to any metaphysical causes.

For nearly two centuries after the rise of the Society of Friends hardly any career or scope for their industry was open to them except business or some form of commercialism. Their energies were therefore mainly turned in this direction.

They had further the extremely valuable advantage of mutual acquaintance with one another through their meeting or Society arrangements throughout the country and in America. Although these connections were primarily for religious fellowship and purposes, yet in their frequent gatherings there was abundant opportunity to talk over business matters. Their religious, social, and business relationships were unequalled by those of any other community in the world. Moreover, they could trust one another as a rule better than outsiders. They were in the best sense one family.

As to the Mennonites, excellent people as they are, I have found them deficient in that frequent collective spiritual communion which is the great basis of all true friendship and unity. They hardly seem to know what collective worship is, and have no meetings for worship as Friends understand them. Their other great defect is an entire lack of official connection between their different meetings, whilst among Friends all the meetings are dependent one upon another in greater or less degree, representatives from one meeting to another are constantly being appointed, and every individual member as far as possible is kept in view and tracked to the world's end.

As to any success of Friends in science and philosophy, there are many helps to quiet and clear and unbiased thought among them which are hardly to be found elsewhere.

Edward Watkins.

Fritchley, near Derby.
*September* 13, 1922.

# ESSAYS

## INDUSTRY AND BIODYNAMICS (Herbert G. Taylor, M.Sc.)

The energy system of man, like that of an animal, is a system which relies for its existence upon energy adjustments or industrial adaptations. In an animal system the potential energy of foodstuffs becomes the kinetic energy of locomotion. The biodynamical character of man-made systems is not so easily stated, but in one corner of man's industrial field we see that coal drives locomotives. In either man or animal, industry may be regarded as a mechanism by and into which potential energy is gathered. The energy runs down, drives the mechanism, and thereby expresses itself in that familiar but complex phenomenon called life. But the animal is simplicity itself when compared with the system which takes in hides, fleece, iron ore, and turns out boots, cloth, and steel rails. And the influences of these industrial powers upon life stand in similar contrast. When we reflect what is the influence of modern industry upon the scheme of life called civilisation, it is clearly evident that, over and above the said boots, cloth, and steel rails, industry produces something which cannot be measured by the gross, the mile, or the ton. It is quite unthinkable that such an influence could be a modern attribute of industry, and yet the scheme of life of any animal is not to be contained in the same category of thought. Our industry, somehow, is as firmly rooted in the past as we are. It therefore remains not to affirm but to demonstrate that industrial organisation maintains, builds, and extends the energy systems which are the biodynamical bases of life. That I shall now proceed to do.

First let us examine the energy system of an animal. Naturalists are agreed that the potential energy of foodstuffs is converted into kinetic energy of locomotion. Suppose we express the conversion mathematically thus: Potential energy = kinetic energy, or

$$\text{P.E.} = \text{K.E.} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1).$$

Does this fully meet the situation? Let us examine some details. A swallow darts rapidly through the air acquiring enough potential energy in the way of insects to enable it to maintain the kinetic energy requisite for catching insects; and there the system ends. A fish obtains enough food to enable it to migrate to another locality when the present supply is exhausted; beyond this it has no energial interest. In some senses, therefore, equation (1) may be taken as true.

Look at another aspect of the energy system in nature. The prime function of all living things appears to be to maintain the species. This operation absorbs energy. During the breeding season the potential energy gathered exceeds the kinetic energy expended by an amount which is passed forward to the coming generation. The biodynamical equation may then be written:

$$\text{P.E.} = \text{K.E.} + \text{L.P.} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (2).$$

The quantity L.P., meaning life pressure, is a quantity fluctuating from zero to a maximum. From this it is easy to see that (1) is a special case of (2). Equation (2) seems to represent completely the energy systems of all present-day animal life.

There is still another aspect of the energy system. From biology we learn that, in animal life of past days, there has been an upgrading or advancement of species. Regarding this matter in the light of the law of conservation of energy, we may write

$$\text{P.E.} = \text{K.E.} + \text{I.E.} \qquad \text{(3)},$$

where I.E. represents internal energy of biological development. If I.E. be allowed to represent the energy requisite for internal biological development and also for propagation of the species, then (2) is a special form of (3). That is to say, so long as evolution persists the energy system is represented by (3), and, when it ceases, by (2).

To understand equation (3) let us examine an energy system in a state of evolution. As an example take a woodpecker. This bird has a very remarkable tongue of considerable length with which to capture insects in the deep crevices about the bark of trees. Any biologist will allow that the tongue was once a simple instrument quite as weak, say, as that of a sparrow. The woodpecker was then well within the period of active evolution, and this is how the activity presents itself to me. At this time the energy system was as represented by equation (3). When an internal energy is engendered in this manner the only outlet appears to be at the points where the industrial mechanism of the animal touches the external supplies of energy. At the tip of the then simple tongue of the woodpecker the available internal energy seems to have concentrated into one cell. In the capture of an insect which the eye could see and the whole body yearned for, this simple cell was driven to such physical extremity that it split into two, as every well-functioning cell would do. This was the beginning of a new anatomical outburst, and soon that portion of internal energy became transformed into so much biological tissue.

In this matter of improved industrial power other functions are involved besides the upbuilding of a mechanism like the tongue. Another example will make this clear. At one period in the evolution of the frog the final anatomical form must have *appeared* to be a tadpole without legs. At this period the internal energy, as in (3), had a value. This energy, as we now know, became a reality in the provision of four legs ; the animal became an amphibian with much greater industrial powers. The provision of legs, it is tempting to suppose, occupied the attentions of numerous generations of frogs. Consider one of the builders who came well within this activity. The anatomical completion within him, as a tadpole, of the equipment as possessed by his parent is, of course, reckoned as the moment of his birth. At that moment he commences his own life, and his duty to the race begins. The internal energy provides the means for new experiences in the development of the frog activities, and the mode of this operation is as follows : The internal energy, concentrated within some particular cell, first provides the energy or the urge for the new experience ; the experience when acquired is recorded in the faculty of remembrance, conscious or unconscious, for the use and advantage of all subsequent generations. The successor of this frog, passing through the stage of recapitulation, has just a little more to learn in the pre-natal stages than the predecessor. Therefore, in these two generations of frogs, there is an increase of knowledge as between the birth of the first and the birth of the second. Every frog nowadays possesses an effectual set of legs and an efficient control centre in the form of a brain. The competence of the brain is, therefore, part of the industrial system. The power to cause motion is the essential requirement. Speaking strictly dynamically, that which causes motion is stored energy. Speaking biodynamically (from what we have just seen) that which causes motion is stored experience. It thus appears that energy biologically absorbed for the improvement of life is transformed from one potentiality to another.

The essential operation in the transformation is the acquisition of a new experience as mentioned above; in this matter we are concerned with forces without as well as within the organism. The operative element within must be admitted to be the faculty of industry; for all organic energy obtains expression here. This lays hold on what is commonly called the environment. See what happens as the frog continues to win its environment. The environment constantly circumscribes and ultimately limits the frog's scheme of life. Each successive builder expands a little farther in the direction of this limit. We may, therefore, regard the frog as driving along a narrow tunnel within the great environment of all natural force, gathering up life as it proceeds. Should the frog, in the process of building, violate the laws of the circumscribing force, death is the result. In this way any industrial outbursts not touching the appropriate environment are effectually precluded from permanent record in the scheme of knowledge; while those industrial adventures which properly touch the environment at once produce a permanent reflection in a manner by which they are handed down through all generations. When biological advancement is complete the subjugation of the environment is accomplished, and the frog, as a living anatomical structure, is constantly transforming into life the energy which surrounds it. All that we have seen of the frog applies equally well to any other creature; therefore, environment, stage upon stage and section by section, pays tribute to the life which triumphs over it. In this grand manufactory potential energy is taken up and transformed into life on an ever ascending scale.

Another sample of industrial activity conveying many useful lessons is that of the common fowl. The fowl produces eggs in abundance, thus manifesting a surplus of industrial energy. The question arises: by which equation, (1), (2), or (3), is the scheme of industry represented? Except in a very minor degree it is not (2); for a very large proportion of the eggs never become fowls. Also, it is not (3), for in the broad aspect of the matter I think I am right in assuming that the evolution of fowls is complete. What, then, does the surplus energy mean? can we reconcile such a state of things with the inertness represented by equation (1)? The surplus, as we know, is appropriated by man and utilised by him as a supply of potential energy. Similarly the surplus energy of cows or bees is utilised as milk and honey. To interpret these things we must view life in terms of environments or the planes upon which it is built. The environment of man is higher than that of fowl, bee, or cow, for man feeds on these creatures, so that his scheme of life embraces theirs. Therefore, it appears, there is a sense in which life may be viewed as an entity embracing all environments all the way from the lowest to the highest. In this view we must accept the idea that life is a division of activities, each element represented by a species set in its own environment.

Look at the frog system again. In the balance of life a certain constant number of frogs is required to subdue the environment, that is, to keep down (again to a constant number) the grubs, insects, worms, etc., upon which frogs feed. Life pressure of the frog, in accordance with equation (2), comes into existence when these said creatures become plentiful; at the same time also the number of frogs becomes great. Then come the marsh birds and the snakes; they reduce the frogs to the appropriate level, absorbing, as potential energy, the life pressure not of any individual frog—for that is already spent—but of frogs as a race. Similarly man absorbs the life pressure of the race of fowls. Viewing the whole mechanism of life in this light we plainly see that the surplus energy of each stratum of environment is of no benefit to the creatures dwelling therein, but is of benefit to the structure as a whole. Each species is complete in itself, living perpetually at constant strength, with an energy system fully represented by equation (1). A stream of energy or life pressure having progressive improvement is constantly welling upwards. At the topmost stratum this energy is set free and the force of evolution is made operative. The topmost creature—man, of course—is not at present giving way to another species; therefore, it appears, a superior form of life is being evolved in which man is the biodynamical agent.

Animals frequently possess some peculiarly formed organ which gives them a hold on their environment. Some we have already noted. Other examples are: the neck of a giraffe; the tentacles of a cuttle-fish; the eyes of an owl; the beak of a snipe. A study of these leads along the now familiar tracks of the biological system. But what of man, does he possess no biological limb of this character? The answer is, of course, the hand. But when we compare the industrial achievements of the hand with those of the special organ of any other animal, we realise the feebleness of the biological conclusion. A snipe's beak, for example, prods through two and a half inches of soft mud in search of week-old potential energy. A departmental aspect of man's industry is coal-mining; how about man's hand here? The cases admit of no comparison; for the biological principles involved are not on the same plane. What now appears to be the absolute industrial system of man has fructified mainly during the past hundred years, but its beginnings are coeval with the beginnings of man as a superior creature.

Primeval man had, like other brutes, reached the end of an epoch in biological expression. At this juncture life pressure made him the agent in a new venture. One day he threw a stone at a passing animal or bird and brought it down. On doing so man reached into an environment not immediately contiguous to his own (no other animal kills its prey without bodily contact); but that fact is of less importance than the means employed to do it. Birds use the wind, fishes use ocean currents, to bring them into touch with their environments; but, note, here is no transfer of internal energy from the animal to the medium employed and, therefore, life pressure plays no part in the scheme. (On the contrary, in the hand of man, through long processes of development, these media have become pneumatics and hydraulics—both agents of potential energy, and consequently media upon which life pressure has had an action.) In the simple act of throwing a stone a quantity of internal energy issues at a man's hand and is transmitted to an external object as a supply of *potential* energy. We must remind ourselves that energy may under some circumstances advance from one potentiality to another. In primeval man, therefore, equation (3) takes a new form which may be written:

$$P.E. = K.E. + P.E_1 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (4),$$

the term $P.E_1$ representing energy transferred to an external system of man and not, as before, to some other species. This transference is without degradation; that is, the quantity $P.E_1$ is transferred in tact and possesses as much power to cause life as some other original energy did when life first began. Clearly, $P.E_1$ is the point of evolution, and although concerning the person of man it is external, it remains, in some manner, internal. How the stone became improved as a mechanical device producing spear, sling, and arrow, is now a matter of history. With these improvements the value of $P.E_1$ constantly increased. Thus we see the beginnings of the growth of a new phase of life in which anatomical changes are not involved.

When the life inhabiting, say, a giraffe, decided to provide a more outreaching instrument in the shape of a long neck, some one mechanical element of that life (a cell) found itself so charged with energy that it started the growth of the desired mechanism. When the life inhabiting man took a similar mechanical advance and, in the effort, actually achieved the transference of a portion of life from man to the surrounding medium, then life, as an entity, commenced a spiritual, as contrasted with a physical, advance.

The clearest interpretation is put upon the matter by regarding mankind as an organism within which man, although changing his function, still retains his physical characteristics; just as a biological cell does within a physical organism. Incidentally we are bound to admit that just as the life within an organism is indivisible so also is the life within mankind.

In an animal we have regarded an outburst of energy as an industrial effort inducing certain animal knowledge and thus carrying the power of proper motion in perpetuity; how do we interpret the new organism in terms of this? It must be remembered that in the instances chosen we have studied the animal at a position considerably advanced in its development, and, therefore, possessing, in some measure, a controlling brain. In the organism conceived by this act of man we have an organism in the rudimentary stages, and in a condition where the brain—or, as we should say, the mind—is a new creation. We should, therefore, quite reasonably expect considerable industrial advances before the mind came to any settled formation, but we should also expect that when this did occur it would do so in a manner quite unmistakable. Two important examples are available to illustrate this point. First: In the year 1666 Newton discovered the laws of motion. All the while from primeval days down to that moment the mechanism of the organism had been advancing, and 1666 marks, within the mind of man, the birth of an element of knowledge promoted by a simple act in the distant past. But notice the conditions of the promotion: only when the mind of man had become so widely prepared and had risen to such a stature as to be capable of associating in one element of knowledge the bases both of mankind and the physical universe. The forces behind the stellar motions are the same as those which issued from the hand of man. Second: Primitive man used fire-sticks to make fire because he "learned by doing" that work produced heat. In the first century A.D. Hero made a steam-engine because he learned in the same way that heat produced work. The organic growth of man benefited greatly by these knowledges, but not until the year 1847 did they become science as the laws of thermodynamics; and then principally on the ground that these ancient forces of man are the same as those by which the suns are formed.

One characteristic feature and universal effect of industry is the division of labour. This is well known and easily recognised either in biological or social affairs. The power in animals to manufacture wings, beak, teeth, claws, etc., becomes, in man, the power to make tools. At first these were of wood, horn, bone, shell, or stone. Later, fire became the agent for the manufacture of tools, and from that time the advance of man becomes appreciable. In pre-fire days the division would be of a low order and the social organism would possess an adhesion practically indistinguishable from gregariousness. When fire became part of man's energy system many important events were precipitated which can easily be interpreted because the same principles are in operation to-day. The first smith (or his equivalent) attracted to himself other men by the unspoken proposition that he and they should bond themselves for mutual advantage. This involves the division of labour and at once suggests the presence of an organic force. The assemblage of men suggests an organism; but are all the essentials of an organism here represented? Is there, for example, any suggestion of a nucleus? In his capacity as a skilled man the smith represents an organisation of knowledge about a personal nucleus. He is also the personal representation of his environment, which he continually transforms into life. So much for the smith; the same might be said of his fellows, and, moreover, we have noticed the same principle in animals. But regarding the smith and his fellows, for a moment, as a number of static organisations, we suddenly see rising in the smith a new personal energy source through which many persons are constrained to act as one in the scheme of livelihood. The new source of biodynamical strength is not the potential energy of foodstuffs absorbed by an industrial mechanism to maintain a physical body, but is of thermodynamical origin with the energy absorbed by an industrial mechanism to maintain a spiritual body. I think that not only do all the essentials of an organism here obtain, but that the position and nature of the nucleus are also made clear. The biodynamical principles here involved may, as in equation (1), therefore be written:

$$P.E_1 = K.E_1 \quad \ldots\ldots \quad (5).$$

By analogy with (2) and (3) we also have:

$$P.E_1 = K.E_1 + L.P_1 \quad \ldots\ldots \quad (6),$$
and
$$P.E_1 = K.E_1 + I.E_1 \quad \ldots\ldots \quad (7).$$

Equation (5) represents the minimum activity of the organism apart from any form of progress. Equation (6) represents the operative system by which the organism is perpetuated. This action—simply that of being "born again"—was once a rudimentary scheme of apprenticeship and involved the essential elements of industrial differentiation and social integration. Equation (7) represents in some manner the distribution of energy within the higher scheme of life of which man is a unit. I do not pretend to interpret the inner meaning of this; suffice to say that on a previous occasion a similar biodynamical state, represented by equation (3), was the basis for a new burst of life of an order represented by equation (4). With the organic advancement of man since he entered the state represented by equation (3), the simple scheme of apprenticeship has become the more elaborate scheme of education in which the several functions—differentiation and integration—demanded more specialised attention. These spheres, although they are the operative elements in the sphere of education, have now drifted far asunder, with education, almost in the nature of an abstract force, hovering somewhere amongst them. The unification of these elements —craftsmanship and unified control—within the sphere of education is a sociological necessity. The same thing might read: the unification of industry and government within the sphere of recapitulation is a biological necessity.

The advance of life to a new plane, as represented by equation (7), has been the cause of much embarrassment to man. This seems to be due to the temporarily unmanageable condition set up by a shift of the centre of the energy system from the finite to the infinite. And, I suppose, as a process in the life scheme leading up to this great change, the division of labour amongst the cells of any living creature was always, for a time, an embarrassment to the personal organisation of the animal. But why, with the animal stage overcome and the advance made with apparent safety on to a new and a higher plane, should there be any organic embarrassment? For this reason: an organism is governed by a consciousness, which means a personal element. In a snail it is *the snail*; in a horse *the horse*; but there was a time, represented by the earlier stages of equation (3) respecting these animals, when the full statement of the consciousness could not have been thus easily expressed. And what is the personal element in our new organism? The answer is in the future. Our present biodynamical position appears to be something arising out of equation (7), which is to that equation as equation (4) is to equation (3). The birth of a new element of life appears to be imminent; beyond that I can say nothing; these matters take their own course. This only do I know: the biodynamical situation is, as it always was, inseparable from the industrial situation, and we can make that what we will.

**THE SPONTANEOUS DEGRADATION OF CULTURE** (Prof. Tenney L. Davis, B.S., M.A., Ph.D., Massachusetts Institute of Technology, Cambridge, Mass., U.S.A.).

"Don't read the Times," said Thoreau, "read the Eternities," and gave words to a scheme for the judgment of excellence, of value, of progress, and of civilisation. To his scheme the common people of France gave tacit endorsement when, in answer to a call by one of the Paris dailies for a popular vote, they named Louis Pasteur as the greatest Frenchman of history.

Whoever would discuss the history of *civilisation* or would think about its rise, its progress, or the contributory value for *civilisation* of various historical circumstances, finds his task complicated at the outset by the meaning of the word in its derivation. Taking the path of least resistance, it is easy for him to think of progress of civilisation as progress in the formation of communities, or, even more, in the communisation or federation of communities, and to regard as of greatest importance in furthering the progress of civilisation those factors of history which have tended most to further the formation of communities. Yet communities pass away: civilisation remains and finds growth in their decadence. King David in the body is gone long since, but the "vicarious existence" that he leads through his Psalms has more importance for twentieth-century civilisation than the splendour of his organised kingdom. We are more concerned with the burning at the stake of Etienne Dolet than with the massacre of eleven thousand virgins, and more with Don Quixote than with his contemporary chivalry of Spain. "Great men form an epoch; the many reflect their age"—and epochs are determined by the particular idea-system which may happen to be current. The history of civilisation is the history of idea-systems. And evolution or modification of idea-system is progress of civilisation.

Anthropologists tell us that the customs of a tribe of primitive people undergo a gradual change as the decades or centuries pass. They undergo certain changes anyway even if the tribe is left wholly to itself entirely isolated from external influences. The ceremonial customs suffer small and gradual modification, the spoken word assumes new and slightly different meanings and intonations; perhaps new modes of weaving grass for baskets are devised, or new shapes for moulding clay into pottery. Similar changes take place among highly civilised people. The transition from the language of Chaucer to the English of the present is change, but it is not progress in civilisation. Such changes are markers which indicate the elapse of time, like the wrinkles on a man's face or an increased facility in doing habitual things—and they have the same kind of interest for the broad-minded student of history that the phenomena of putrefaction have for the student of comparative morphology. They are not structural changes of idea-system.

Darwin is a more important figure in the history of European culture than any of his contemporary monarchs. Napoleon ravaged the face of Europe, and hardly more than a century later his effect upon its thinking is scarcely discernible. We remember that Archimedes was working on geometrical problems when the siege of Syracuse broke through, that he was too absorbed in figures written in the sand to give heed to soldiers who accosted him, and that he was killed—for his indifference to the things of war. Archimedes is a factor in our present civilisation, while the war that killed him is romance or dry dusty history according to how we view it, but nothing more. The reading throughout Europe of the imagined adventures of Pantagruel probably had quite as much to do with bringing about the Protestant Reformation as did the actual posting of the theses of Luther. Indeed, the criterion for judging the value for civilisation of the many factors which influence it is to be found in an examination of the effect which these factors have produced, not merely in an examination of their effect upon their own times, but in one of their depth and permanence, in a measurement of the length of the shadow which they cast through the times that come after them.

These considerations are well understood and have been discussed broadly and in detail in a wide variety of places. They may be summarised in the propositions—that progress of civilisation or of culture comes about through changes of idea-system; indeed it is nothing other than change of idea-system—and that changes of idea-system have been accomplished by the ideas of individuals. It would follow that progress of culture is due ultimately to the causes which have provoked individuals to have the ideas which have altered the idea-system.

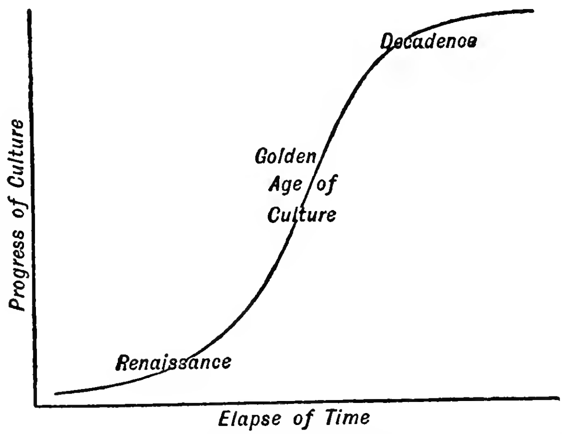
Psychologists need only enumerate instances to make it clear that fruitful and important ideas come to an individual as the result of his being subjected to a crisis of one kind or another, to an unusual circumstance which provokes an unusual reaction. Such crises are provided by war, as Teggart has pointed out in his *Processes of History*; they give rise often to deeply religious reactions, as the "Varieties of Religious Experience" make manifest; they are found in falling in love, in bodily infirmity, in the effect of alcohol, in fear, in anger, and in the presence of death. They undoubtedly occur with greatest frequency when the medium in which the individual finds himself provides the greatest possibility of predicament. Stevenson says that "every young man becomes something of a poet when he falls in love," and we may be confident that there would be more lyric poetry of permanent value in the world if more of us loved harder or were not so soon done with it. The fable of the Garden of Eden has more than a metaphysical significance, for the discovery of sin was coincident with the beginning of intellectual activity. The most fertile period in the cultural development of modern Europe was a period of petty princes with petty quarrels, of small independent cities, of vice, disease, brigandage, pride, pomp, and superstition, a time when often men dared scarcely to call their names their own. We read the autobiography of Cellini and wonder almost that such a man did not produce a second and greater Perseus.

While the Great War has apparently accomplished but little in determining the destiny of Europe, it has done much for the future culture of the peoples which were concerned with it. This is especially the case with the Allies. The French will benefit most, next perhaps the Americans. The sensitive and highly reactive Frenchman met many predicaments, those of a kind which are always provided by war—and with this kind he is familiar—but those of other kinds also, those furnished by the American in his midst, by the Canadian, the Australian, the New Zealander, people strange to the ways of the Boulevard des Capucines, foreign alike to the frankness and the gall of his sunny land. More than a few Americans heard the honest, full, man's laugh of Rabelais; they drank of Chateauneuf from the garden of the Popes; they learned to know the pertness of the coquelicot of Picardy. "But what good came of it at last?" The question carries its own answer if it is worth debating. The already tremendously increased output of science, invention, art, literature, and philosophy in France and America is evidence that the Allies really won the war.

When the group has attained a condition of inward complexity sufficient to provide a wide variety of predicament to the individuals which constitute it, adequate to stimulate them to frequent, diverse, and unusual reaction, then the culture of the group grows rapidly for a time. This growth is self-accelerated, for it gives rise to new predicaments and the predicaments give rise to new growth of culture.

Chinese culture took its rise in the mountain passes toward Thibet, where the practical military advantages to be gained by occupation were repeatedly contested by warring tribes. Diverse traditions and ideas came into conflict. The warring individual, confronted with strange situations different from those which arose within his own group, met them with new reactions. Out of the conflict new ideas arose foreign to both of the older warring traditions. These incorporated themselves in the idea-systems of the combatants—and seeds of a broader culture were sown. Still other tribes, pressed onward by the continental drift of peoples, made their claim for possession of the pass. It mattered little which side lost or won ; new ideas, new reactions resulted, new vistas were opened—the beginnings of Chinese culture spread eastward into fertile, flatter country. In the course of due time fortifications were built strong enough to hold out invaders. The seeds sown by repeated conflicts began to germinate, within the peaceful and protected area the incubation of ideas set in—and Chinese culture had commenced.

The case with Greece was a similar one. One people after another were pushed down into the Greek peninsula, bringing with them such culture as they had, there to clash with pre-existing culture. When the Macedonian Empire across the head of the peninsula put a lid upon the box, disturbance within the peninsula approached an equilibrium and the glory of Greece blossomed to maturity.




Curve representing the progress of a self-catalysed chemical reaction ; represents also the rate of growth of the culture of a single group.

The growth of culture is like the progress of a self-catalysed chemical reaction, for the effect of the process is to cause an acceleration in the process itself. Each process may be represented by the same curve—and each process wears itself out in the end.

Guncotton is an essentially unstable substance. No matter what the conditions under which it is stored, it breaks down spontaneously into simpler substances. If it is kept in a vacuum where the gaseous products of its decomposition are constantly removed, it breaks down but slowly. If, on the other hand, it is stored in an ordinary atmosphere, the nitric oxide which it gives off combines with oxygen and moisture of the atmosphere to form nitrous and nitric acids. These strong acids act upon the guncotton, hastening its further decomposition and leading to the production of further nitrous and nitric acids which further hasten the decomposition, and so on. The spontaneous decomposition of guncotton in an ordinary atmosphere starts slowly and becomes increasingly rapid, until at last it results either in the spontaneous combustion of the mass, or it slows down because the supply of reacting guncotton is exhausted.

So also with culture. The causes which produce it in the first place, namely, the predicaments, in producing new individual reactions which lead to changes of idea-system, produce an increased complexity within the group and new predicaments, which are the further cause of further changes in the idea-system. The process becomes increasingly rapid as time goes on. It would continue to accelerate endlessly were there no factor tending to retard it. But such a factor is found in the very nature of the medium in which culture has its being. For that complexity of the group which tends toward the production of predicaments, as it increases, makes an increasing demand for an internal regulation which reduces the complexity, eliminates predicaments, and shuts off the generation of culture at the fountain-head.

It may be that people get together, as the military love to tell us, for purposes of defence ; but the defence is against other people who have come together (for defence perhaps ?)—and the argument fails far from conviction. Savages find recompense for staying with their tribe in the protection against wild beasts and the jungle, and against the elements, which the group is able to afford. But the causes which hold the tribe together are not the causes which bring together the larger groups and stimulate them to grow still further and to maintain for a time their individual existence. These primitive causes are not effective in groups which have survived the first clashes that produce predicaments and have entered upon their renaissance of culture.

Culture itself brings people together, and holds them. If a poet has songs to sing, people come to hear. To the artisan they come to learn his trade, to the physician to learn the manner of his miracles. Common languages grow up. Everywhere within the group an audience may be found for the individual who has something to say or to show. Scholars appear, research and speculation of all kinds go on—and interested individuals are always on hand alert to read, to listen, or to watch. When Benjamin Disraeli remarked that the civilisation of a nation may be measured by the amount of sulphuric acid which it consumes, he spoke in reference to the present question. Had he paused to point out that ink among many necessaries of culture requires sulphuric acid for its manufacture, he would have clinched his contention. And if now we take note further that ink flows most freely and with best effect when the environment of the thinker is tranquil, we have reached by one route the inference, obvious enough by any, that the propagation of culture is easiest in an orderly medium.

The spread of culture is like the propagation of ripples in a mill-pond. There will be no ripples unless there is the disturbance, the predicament, the stone thrown in, to produce them in the first place. And there will be no ripples unless the surface of the pond is placid enough to give them play. A strong wind upon the water or too many stones thrown in at once is adequate to prevent them. And culture, growing out of predicaments and itself producing new predicaments, itself cannot ripple except in the places where predicaments are not.

The spread of ideas by writing or print requires open ways of transportation, communication, and travel. Sheltered places are needed for verbal interchanges. Schools in unpoliced communities would be practically impossible. The universities of Europe came into existence at a time when scholars could live free from the instant necessity of taking up the sword. A man cannot think his clearest unless he have undisturbed sleep. Nor can he speak well nor write for long on an empty stomach. Scholars thrive only in peaceful places where food, grown by others, is delivered to them in exchange for their own productions. Indeed, it may be taken at once that organisation and regulation, the practice of the " bigger, better, busier" idea, prohibitory legislation, rules, customs, practices, stabilised and predictable interchanges of all kinds, that all of these factors make easier the propagation of culture. The civilised group devises means for the easier spread of civilisation.

It is thought to be equally obvious that these factors, in smoothing the way for culture, at the same time shut off its generation at the source. If the beginnings of change of idea-system are found in predicaments, it follows without discussion that organisation and regulation, police and prohibition, etc. etc., however desirable they may be for other reasons, do nevertheless abolish predicaments and cut off the growth of culture at the point where the growth begins.

The growth of culture follows the same law as does the self-catalysed decomposition of guncotton. It signs its own death-warrant. It gives rise to circumstances which cause its own cessation. For its easier growth it organises and regulates—and it chokes itself thereby. If we look at the history of ancient civilisations, we find them epitomised in the history of a wisp of guncotton ; at the end either spontaneous combustion or cessation of change from self-suffocation.

In reaching the conclusion that the growth of the culture of a single group follows the same law as does a self-catalysed chemical reaction, I have proceeded without any expectation that the law would apply with mathematical exactness. It does not seem likely that its mathematical exactness in this connection will ever be demonstrated—for we know of no way by which culture may be estimated quantitatively. All the more remarkable, then, is the fact, recently pointed out,[1] that the rate of growth of the population of the United States, and presumably of other single groups, actually does follow this law. The question of the interconnection of culture and population arises at once, but it will not be discussed at this place, for it hardly falls within the scope of the present paper. Yet the fact that the growth of each follows the same law may be taken as inductive evidence of the probable truth of the present argument.

It is thought that the foregoing argument contains nothing novel, except perhaps in its arrangement and in the conclusion to which it leads, nothing in its premises which has not already been pointed out elsewhere with greater richness of detail. The various considerations which it involves have been expounded in many places by anthropologists, psychologists, and historians. I suppose them to be so familiar that I have here contented myself merely with linking them together. The argument may be summarised :

1. Progress of civilisation or of culture comes about through changes of idea-system. Rate of this change is rate of production of culture.

2. Changes of idea-system have been accomplished by the ideas of individuals.

3. Individuals get bright ideas as the result of being subjected to predicaments.

4. For a time the growth of the group provides an increase in the variety of predicaments to which an individual can be subjected, and so promotes change in the group's idea-system.

5. Ultimately the growth of the group causes it to insist upon internal organisation and regulation. This abolishes predicaments, reduces the possibility of diverse individual reaction, and stifles the germination of culture at its source.

Now that the foregoing is written, the temptation is strong to moralise. In this twentieth century it seems that we study Nature and learn her laws, not apparently as the ancients did in order that we may accommodate

[1] Raymond Pearl and Lowell J. Reed, " On the Rate of Growth of the Population of the United States since 1790 and its Mathematical Representation," *Proc. Nat. Acad. Sciences*, **6**, 275. June 1920.

ourselves to them, but rather that we may bark our knuckles and batter our heads in an effort to oppose them. There is a law of supply and demand in Nature, and we appoint commissions whose duty it is to strive to render it inactive by the regulation of prices. There is a law of the survival of the fittest, and if any individual among us shows himself unfit by reason of heredity or the accidents of his own existence, we foster and nurse him and keep him alive, but the fit we send to war or leave unaided in the fell clutch of circumstance. There is in Nature a law of the spontaneous degradation of culture, and we bend our efforts toward hastening the accomplishment of its operation. We organise and prohibit and regulate—and shut off culture at the source of supply. I point out the facts—but will not moralise. To urge here against the suicide of culture would be anarchy.

# ESSAY-REVIEW

**THE DYNAMICS OF DISTRIBUTION.** By A. G. Thacker, A.R.C.S., being a review of: **Age and Area.** By J. C. Willis, Sc.D., F.R.S. [Pp. x + 259.] (Cambridge University Press, 1922. Price 14*s*. net.)

The sub-title of this book is: " A Study in Geographical Distribution and Origin of Species." Dr. Willis was for many years Director of the Botanic Gardens at Kandy, Ceylon, and he subsequently held a similar position at Rio de Janeiro. He has made most detailed studies of the distribution of plants, especially of those found in tropical and southern countries. He has collected laboriously a mass of most interesting statistics, and he claims to have discovered a fundamental principle which he believes underlies the geographical distribution not only of plants but also of animals. It is this principle which he has named " Age and Area." The hypothesis is simple. Take a group of allied species and find the average area covered by them. Then take another group of allied species, fairly closely related to the first group, and find the average area covered by them. The two average areas are then believed to indicate the average ages of the two groups, that is, the relative ages, not any absolute figures, of course. If the average area of the second group be greater than that of the first group, then it is inferred that the average antiquity of the second lot of species will also be greater than that of the first lot. The principle is not to be applied to individual cases; and it must not be applied to groups of species which are not fairly closely allied. But with these qualifications (the necessity of which is, of course, obvious) age and area are conceived to vary together. The hypothesis may, however, be given in Dr. Willis's own words, his definition (p. 63) being as follows: " The area occupied at any given time, in any given country, by any group of allied species at least ten in number, depends chiefly, so long as conditions remain reasonably constant, upon the ages of the species of that group in that country, but may be enormously modified by the presence of barriers such as seas, rivers, mountains, changes of climate from one region to the next, or other ecological boundaries, and the like, also by the action of man and other causes."

It will be noticed that this definition is well hedged with qualifications; but in point of fact, unless the author's statistics are susceptible of another explanation, there is singularly little sign of the " enormous modifications." The book is divided into two parts. The first part is entitled " The Present Position of Age and Area," and contains nine chapters, of which five are more or less introductory. Chapters VI and VII constitute the core of the book. They describe the proofs of the hypothesis and give the supposed " confirmation by prediction." Part II is entitled, " The Application of Age and Area to the Flora of the World, and its Implications," and has thirteen chapters, of which four are contributed by other writers, namely, Dr. H. B. Guppy, Prof. J. Small, Mrs. E. M. Reid, and Dr. Hugo de Vries. The most important chapter in Part II is, however, that entitled " Size and Space." The principle there enunciated is really an extension of the idea of age and area. By " size and space " the author means that a large genus (a genus with many species) will, on the average and taking groups of allied genera, have a wider distribution than a small genus, whether the distribution be measured by the range of the genus as such or by the range of the most widely spread species in it. But to return to Chapters VI and VII. In examining the flora of Ceylon, Dr. Willis found that the range of endemics was usually less than the range in Ceylon of species which extended to the peninsula of India. Since some of the endemics were presumably species that had arisen after the separation of Ceylon from the mainland, and since the average age of endemics was, therefore, less than that of species shared by Ceylon and India, Dr. Willis thought that these facts showed that age and area varied together. Furthermore, he found that the average range in Ceylon of the species that extended into peninsular India (but not farther) was less than the average range in Ceylon of the species which extended into peninsular India and into the outside world as well. These were the facts that formed the basis of the conception. Casting round for another region on which to test these views, the author then thought that New Zealand and its neighbouring islands would furnish such a test. The Kermadecs, the Chathams, and the Aucklands, were once part of a greater New Zealand. Therefore the New Zealand plants found in these islands should be ancient species. Therefore they should, on the hypothesis, be more widely spread in New Zealand, on the average, than those New Zealand species which do not reach the islands. Moreover, those found in only one group of islands should have a less wide range than those found in two groups, and those found in all three groups should have the widest range of all on the mainland. And it was found that the figures were entirely in accord with all these expectations : the range in New Zealand of the species which do extend to the islands is markedly greater than the range of those that do not extend to the islands, and the batches of species arrange themselves in the required graduated series, according as they occur in one, two, or all three groups of islands. And the author says : " There is no conceivable reason why ranging to one or more of these little groups of islands, and to any one of them . . . should make a species more widespread in New Zealand than the average, unless it be the mere fact that to have been able to reach the islands at all it must have been above the average age in New Zealand, and thus have had more time in which to spread." Here we have the essence of the matter. And the discussions in later chapters largely depend upon the validity of this fundamental " Age and Area " proposition. It should be said that Dr. Willis considers that his hypothesis supports the theory of evolution by mutations as against the Darwinian theory of the Natural Selection of continuous variations ; and it is for this reason, of course, that we have the chapter by De Vries, though it is stated that neither he nor the other writers above mentioned are necessarily committed to all Dr. Willis's doctrines.

The subjects discussed by Dr. Willis extend into many branches of biological science, and in a brief space it is only possible to consider a few of his most salient points. The most obvious comment is, of course, that species and genera do die out, and that therefore there are diminishing ranges as well as expanding ranges ; of course Dr. Willis does not ignore this point, but he thinks that very few of the small-range species are, in fact, dying species. If this be so, the total number of species in the world must of course be increasing. It may be true that the number is increasing ; and it is also certainly true that, since range is measured " by the most outlying stations," and since the decay of a species is likely first to manifest itself by discontinuities in distribution rather than by steady contraction of range, the dying species will not show so much in small area groups as will the young species, even supposing that the total number of species in the world is remaining constant. But apart from this general and very obvious consideration, there are some highly controversial mathematical problems in the book. The author appears to be insufficiently critical of his own hypothesis. Nothing is more important than the New Zealand case, but there are fundamental aspects of the problem involved in this case which Dr. Willis ignores.

It is necessary to recall in imagination what happens when a small fragment is severed from a large island. In the large island there will no doubt be species with varying ranges; some species will be almost or quite universal; others will be very local; others again will have intermediate ranges. It is here that the ordinary law of probability comes into play. The severed fragment of the island will have, at the moment of separation, a higher percentage of the species with large ranges than of the species with small ranges. Of the species that are universal it will have 100 per cent. Of the very local species, it will have few or even none. Hence, from the very moment of separation, and before any new species have come into existence on the main island, the average range on the main island of those species that are also on the little island will be greater than the average range of all the species on the main island, and, *a fortiori*, greater than the average range of those species which do not extend to the little island. This of course is a law of chance that is not applicable to individual species, but only to groups of species. But it is this, and nothing more, that we find in New Zealand; and the phenomenon is explicable by the ordinary law of probability without any need for the age and area hypothesis. Taking large numbers of species, the chances of those species being represented on the Kermadecs, Chathams, or Aucklands, will have varied with their ranges in ancient greater New Zealand. A homely example will perhaps make this point even more clear. Take a group of five mammals that are widespread in Great Britain, such as the rabbit, the brown rat, the wood mouse, the weasel, and the stoat. Then take another group of five mammals that are rare and local in Great Britain, such as the wild-cat, the pine-marten, the polecat, the red deer, and the yellow-necked mouse. Now let it be supposed that fragments are struck off Great Britain. A moment's consideration will convince anybody that most of the animals of the first group will occur on all the fragments, and that on many fragments all five species would occur. On the other hand, it is equally obvious that a single fragment could hardly include all five species of the second group, and that many fragments would miss all five of them. Hence the average range in Great Britain of the species on any such fragment would be greater than the average range of all the ten species, and it is to be noted that such a result will be reached, whatever be the cause of varying ranges on the mainland.

The law of probability is also applicable, though in a different manner, to the question of "size and space." Dr. Willis finds that the most widely dispersed species of a large genus is (again taking averages of a number of genera) more widely dispersed than that of a small genus. But this fact is merely in accordance with ordinary biometrical expectation. Whatever may be the real causes of varying ranges among species, if one selects the widest range of a group of, say, twenty (a large genus), it is likely to be wider than the widest of a group of, say, three (a small genus). The fact that, on the average, the range of a genus, as such, varies with its size is merely another aspect of the same phenomenon. The error consists in supposing that a small group of species is comparable to a large group of species merely because each is classed as a single genus. A genus of one species is a homogeneous assemblage of individuals. A genus of three species is a more heterogeneous assemblage. A genus of twenty species is a much more heterogeneous assemblage again. The real meaning of the "size and space" principle is therefore that, as we study more and more heterogeneous assemblages of organisms, we find that their geographical ranges become larger and larger. And since, on the average, a large stretch of country will possess greater variety of character than a small stretch, the conclusion we reach is that the heterogeneity of organisms varies directly as the heterogeneity of the environment, a result which is entirely congruous with Darwinism. And that the statistics are governed by probability is indicated by certain figures given on p. 114, which tend to show that the *mean* range of the species of a genus is very constant, irrespective of the size of the genus.

Although many of Dr. Willis's data appear to be susceptible of other explanations besides his own, this attempt to explore the dynamics of distribution is exceedingly interesting, and is certain to give rise to much controversy.

# REVIEWS

## MATHEMATICS

**The Mathematical Theory of Probabilities.** By ARNE FISHER. Translated from the Danish by C. DICKSON and W. BONYNGE. Vol. I. Second Edition. [Pp. xxix + 289.] (New York: The Macmillan Co.)

MR. FISHER's book, the first volume, consists of three parts, the first dealing with the mathematical theory of probability leading up to Baye's theorem, the second dealing with the theory of dispersion and the application of various criteria in considering whether a series of errors of observation are due to chance or to certain definite laws, the third dealing with the analysis of frequency distributions. He hopes in the second volume to deal with the theory of correlation.

The author has undertaken a great task to treat adequately the methods of modern statistical analysis, and naturally, at a certain stage, he has to abandon the general theory for the particular theory, and after the first part he has followed the methods of the Scandinavian and Russian schools. The application of the theory of probability to statistical problems has developed rapidly in recent years on the Continent, in America, and in England, and a great deal of work done in Scandinavia and in Russia has never become well known to the English school owing to the language difficulty. Mr. Fisher is able to fill the rôle of liaison officer and present the work of Continental writers in an understandable form for the benefit of English-speaking workers, and on this account his book is of great service, and for this alone we are in the author's debt.

The first part of the book, being the development of the theory of probability as the foundation of the theoretical basis of the modern statistical calculus, does not suffer, as most works on probability suffer, from an over-treatment of those interesting problems in probability which have academic interest, but are not links in the chain of argument which leads up to Baye's theorem, but it gives a careful and good treatment of the fundamental theorems in probability. In these days, when the validity of Baye's theorem is once again being assailed, it is good to be able to turn to Mr. Fisher's book, where he gives a very full discussion of both sides of the argument concerning this fundamental problem, and enables the practical statistician to feel sure that there are good reasons why he should accept this theorem. It would have been of interest to note his remarks on Prof. Pearson's paper in *Biometrika* (1921) on "The Fundamental Problem of Practical Statistics."

His connecting chapter on "The Law of Large Numbers" between the theory of probability and the treatment of statistics serves a very useful purpose, and enables the reader to see more clearly the connection between classic probability and modern statistical analysis. In his discussion on the "mean" we would have preferred more cogent reasons for his use of the arithmetic mean as the best value to be obtained from a series of observations. He frankly says: "Since we have no a priori reasons for choosing any one particular value of the various $a$'s . . . in preference to any other, we might give equal weight to each set and take the arithmetic mean. . . ."

In his treatment of frequency distributions he follows Gram, Thiele, Charlier, and uses the method of Semi-Invariants and illustrates his method by many examples, generally contrasting his results and the length of time of working, with the results obtained by submitting the same material to the Pearsonian methods. We may note in this connection that he does not submit the results he obtains to the test of goodness of fit, but probably he will discuss this in his second volume. It appears that for the most part he uses curve-fitting methods as a means of graduation rather than with the idea of obtaining theoretical laws which his data might obey, and which could probably be more easily represented by expressing his theoretical distribution in the Pearsonian manner rather than by means of the Laplacean Probability curve and its derivatives. It may be pointed out that the Pearsonian curves are unimodal, and will only fit observational data well when these are unimodal in form, whereas his theoretical curve is multimodal in form and will naturally fit a frequency distribution of the type he shows on p. 258, where the Pearsonian method would fail. ("Age Distribution of Male Employees in the Bell System.")

We would rather the author had given more discussion on the question of the method of least squares; we disagree here with Mr. Fisher and hold that the principle of least squares is invariably interwoven with the Normal Law of Errors. On the whole, however, we have to thank the author for his very able and successful attempt at a good book on statistics, and only wish that he will follow it up with the second volume at an early date.

E. C. Rhodes.

**New Mathematical Pastimes.** By Major P. A. Macmahon, R.A., D.Sc., F.R.S. [Pp. vii + 116.] (Cambridge: at the University Press, 1921. Price 12*s*. net.)

Major Macmahon has generalised the game of dominoes and has produced a variety of extremely diverting new mathematical pastimes. In the simplest form there are twenty-four pieces, each an equilateral triangle, divided into three by lines joining the angular points to the centre, the compartments being coloured with all possible combinations of four colours. The game is to fit the pieces together to form a large regular hexagon, with certain contact conditions and certain external boundary conditions. For example, we may lay down that a compartment shall be adjacent to a compartment similarly coloured, and that all the external compartments shall be coloured red. The boundary conditions with the above contact conditions must, of course, be restricted so that each colour occurs in the boundary an even number of times. In the table at the top of p. 5 it is stated that there are eight such schemes for the boundary, but the author then proceeds to give as an illustration a case not included in the table, with six of one colour and six of another in the boundary. Further varieties may be obtained by selecting certain ten of the pieces containing only three colours, or by selecting the thirteen which contain a particular colour, the shapes into which the pieces are to be fitted being then a flat hexagon and a blunted triangle. It is not always as simple as it sounds to fit the pieces together correctly, and we are encouraged by a quotation from Holinshed: "And when he had taryed there a long time for a convenable wind, at length it came about even as he desired." The present writer has made himself a set of pieces and has wasted a good deal of his own time and that of his friends, both mathematical and non-mathematical, very pleasantly on the above pastimes alone. But this is only the fringe of Major Macmahon's subject; he goes on to squares, right-angled triangles, cubes, and hexagons with ever-increasing complexity and with a wealth of quotation from the most diverse sources, rare and familiar.

The second part, heralded by a passage from *The Consolation*, deals with a transformation theory of the first; the pieces are now uncoloured, but are no longer of the same shape, the external boundary being modified in accordance with the colour of the corresponding piece and the contact-law assumed, but so that the new pieces will still fit together. A bewildering variety of curious shapes and jig-saw puzzles is thus obtained, and the author has to call in the help of Latin and Italian quotations to express his feelings. "Quel che è nuovo è sempre bello."

Part III examines the problem of fitting together pieces of the same size and shape so as to cover the whole plane, a subject on which (and on the similar problem for space) the author has recently communicated two learned papers to the *Royal Society* and the *London Mathematical Society*. He calls attention to the sad lack of initiative on the part of designers of parquet floors, carpets, and wallpapers which involve repeating patterns, and certainly anyone who possesses this book will be overwhelmed and possibly scared by the patterns which he might have to live with.

This is an extremely well written and entertaining book; we share the author's regret that it was impracticable to print Part I in colours, but the reproduction of the many complicated diagrams leaves nothing to be desired.

F. P. W.

**Frequency Arrays.** By H. E. Soper, M.A. [Pp. 48.] (Cambridge: at the University Press. Price 3*s*. 6*d*. net.)

The author of this little book of less than fifty pages illustrates the uses to which his symbolic method of treatment of various statistical concepts may be put, by demonstrating many well-known propositions in the theory of mathematical statistics. His aim has been merely to show that, by the use of logical symbols and "ascribing to such symbols the laws of common algebra in their combination, the description, analysis, and derivation of frequency distributions are often much simplified." He has certainly succeeded in arousing interest, if only on account of the fact that he has concentrated in his few pages matter which, when treated by the usual methods, requires ten times as much algebraic analysis. This pamphlet should be read by all mathematical statisticians.

E. C. Rhodes.

**Practical Least Squares.** By O. M. Leland, B.S., C.E. [Pp. xiv + 237.] (New York: McGraw-Hill Book Co., 1921. Price 15*s*. net.)

The aim of this book is essentially practical, as its title states; it is intended to show the engineer and surveyor how to adjust his observations. The knowledge of mathematics assumed is very small indeed; it is even considered necessary to explain in a footnote what is meant by the geometric mean of two quantities. Any integral which occurs is examined in detail, but, surely, even an engineer nowadays ought not to accept without question the inversion of the order of integration in an infinite repeated integral which is assumed in the evaluation of $\int_0^\infty e^{-x^2}\,dx$ on p. 214. But these are details; the main idea is to show how the calculations can be done with the minimum of labour and the minimum chance of mistake, and this is successfully carried out.

A general introduction classifies errors of observation into systematic, theoretical, instrumental, personal, and accidental, and explains that it is only the last which are considered in adjustments. The law of error which, says the author somewhat confusedly, "has been completely derived and tested, later, in a multitude of cases, with entire satisfaction," is then assumed (Gauss's derivation is given in an appendix), and the principle of least squares is deduced therefrom. Chapters II to V treat in detail, with numerical illustrations and a note on tables and calculating machines, the adjustment of direct, indirect, and conditioned observations. The practical method of solution of the normal equations is given in a form due to Mr. Doolittle, of the United States Coast and Geodetic Survey. A digression of fifty pages deals with the particular case of the adjustment of triangulation, and we then have an account of empirical formulæ and the determination of the precision of observations and results.

The appendices include an interesting historical sketch of the subject and a useful bibliography, together with tables of the error function, and numerous, though one would have thought unnecessary, plates of typical curves, straight lines, parabolas, logarithmic and sine curves.

But we must protest against the word "explement," which is to be found on p. 17.

F. P. W.

## METEOROLOGY

**The Climates of the Continents.** By W. G. Kendrew, M.A. [Pp. xvi + 387, with 149 figures.] (Oxford: at the Clarendon Press, 1922. Price 21*s.* net.)

The aim of this book is to give brief general descriptions of the climates of all parts of the world. There has been hitherto no single publication in English containing such descriptions, and it has been a laborious task to extract the required information from the widely scattered literature in which it is embedded. Mr. Kendrew's book, though in a certain sense comprehensive, does not attempt the thoroughness of treatment attained in Hann's famous *Handbuch der Klimatologie*, and attention is concentrated on wind, temperature, and rainfall, with only general references to sunshine, cloudiness, and humidity. The limitation is fully justified by the compactness and extreme lucidity of the work; the author shows, indeed, a rare talent for condensing and vivifying large masses of dry statistics, and his book reads as easily as a novel. A welcome feature is the inclusion of descriptions by residents of the way in which certain climates affect the white man, such, for instance, as those of the Punjab and Senegambia. These are very vivid. The diagrams are all very clear and simple. The book is self-contained and does not require of the ordinary reader either a knowledge of general meteorology or a collection of books of reference.

E. V. N.

## PHYSICS

**A Dictionary of Applied Physics.** Edited by Sir Richard Glazebrook, K.C.B., F.R.S. [Vol. I (Mechanics—Engineering—Heat), pp. ix + 1067; Vol. II (Electricity), pp. vii + 1104.] (London: Macmillan & Co., 1922. Price £3 3*s.* net each volume.)

It is rather remarkable that no dictionary of physics or natural philosophy has been published in English for many years in spite of the fact that it is the branch of science which, more than any other, has attained its present position by the efforts and achievements of workers in this country. The several editions of the *Encyclopædia Britannica* have, it is true, provided a number of short monographs of very great value, but these, for the most part, have necessarily been of a general or much condensed character. In view of the long unfilled gap in the literature of the subject, it is most encouraging that, at a time when the cost of printing and producing books is so excessive, a firm of publishers should be willing to undertake the publication of an extensive work of the kind. The explanation is to be found in the title of the Dictionary; the contents are nominally restricted to the application of physical methods and discoveries to the necessities of modern civilisation.

The usefulness of chemistry in this connection has long been directly obvious and that science is well provided with comprehensive reference-books ; but the work of the physicist has usually reached the industrial world by way of the engineer, so that physics has long been regarded as rather an academic science out of touch with human needs : indeed, since for that very reason the physicist rarely came into contact with industrial conditions, it inevitably tended in that direction. The war altered all this, and one of its few beneficial results has been the recognition, by at least a small part of the manufacturing interests of the country, that the physicist is able to give valuable assistance in the solution of many of the technical problems of industry. With that recognition has come a new grouping of scientific knowledge, a combination of physics and engineering in which the former is the dominant partner, and it is with this grouping that the volumes under review are mainly concerned. Realisation that the works chemist has need of some knowledge of engineering has already resulted in the provision of college courses in chemical engineering ; it is to be hoped that the time is not far distant when similar training will be available for the physicist.

The Dictionary has been arranged so that those interested in only one or two branches of physics need not purchase the complete work in order to cover the whole of the ground with which they are concerned. The arrangement in each volume is alphabetical, but the volumes themselves deal with specific parts of the subject. The contents of the first two volumes have already been indicated ; Vol. III will contain the articles on Meteorology, Metrology, and Measuring Apparatus ; Vol. IV those on Optics, Sound, and Radiology ; and Vol. V those on Metallurgy and Aeronautics. In order that each volume may be complete, a certain amount of overlapping has been admitted, *e.g.* Vol. I contains a complete account of the instruments used for measuring pressure and temperature (including the Resistance Thermometer and Thermocouples), which might perhaps have been looked for under Measuring Instruments, while Vol. II contains an article on X-rays which will no doubt be amplified in the volume on Radiology. This subdivision of the subject-matter in separate volumes, while greatly to the advantage of the limited purse of the average physicist, is presumably also responsible for some of the few, but conspicuous, lacunæ in the volumes already published. Thus in Vol. I there is no reference to hygrometry, and Vol. II gives no information about electroscopes, machines for generating static electricity, the ordinary induction coil, or any kind of medical application of electricity. There are other omissions which can hardly be repaired elsewhere—notably in connection with those subjects studied under the head of general properties of matter, such as surface tension, diffusion, osmotic pressure, and the kinetic theory.

The authors of the great majority of the articles have a first-hand knowledge of the subjects on which they write. This is essential in an authoritative work, but, when space is limited, is apt to lead to a biased choice of material. In these articles such bias is remarkable for its absence, where it occurs the omissions may be defended on the ground that the practical side of the subject is to have preference. A surprisingly large proportion of the material appears in book form for the first time, having been collected from widely scattered and often extemely inaccessible papers. Articles notably rich in information of this character are those on Air-pumps (by the Research Staff of the General Electric Co.) ; Calorimetry (Ezer Griffiths) ; Heat Convection (F. H. Schofield) ; Friction (T. E. Stanton) ; Viscometry (W. F. Higgins) ; and the Realisation of the Absolute Scale of Temperature, a very notable essay by Day and Sosman.

The plan adopted by most of the writers of the longer articles is to give a general introduction, and then, under suitable headings, an account of the methods employed in the most important researches, with diagrams of the apparatus and tabulated details of their results. Some of the articles contain useful practical hints and a bibliography; but more often the latter is replaced by the less satisfactory system of scattered footnote references. The diagrams and illustrations are very numerous, though sometimes on rather too small a scale to be really useful (*i.e.* usable without reference to the original paper). In a few cases descriptions of apparatus have been omitted in favour of a more extended discussion of results. It is obvious that the articles are too numerous and lengthy to permit of anything but the most general description and criticism. Some of the more noteworthy articles in Vol. I have already been indicated. Others which ought also to be mentioned include those on Thermal Expansion (A. W. Porter); Thermodynamics (Ewing); and Pyrometry (Griffiths); together with others on various engineering matters such as Elastic Constants (R. G. Batson), Balancing of Prime Movers (Dalby), etc.

Vol. II, on Electricity, will be found to be of even greater value to the average physicist than Vol. I. Among its outstanding features are Albert Campbell's contributions on Electrical Capacity and Inductance. These contain many detailed practical hints in addition to descriptions of all the recognised methods of measurement and of the special apparatus required in using them. Similar remarks apply to F. E. Smith's articles on Resistance and Systems of Electrical Measurement, which contain accounts of the latest methods of absolute measurement, and for the setting up of copies of the International Standards. Magnetism is treated very fully from both the practical and theoretical standpoints in articles by Chapman, Chree, Honda, Taylor Jones, Oxley, etc., and the latest developments in thermionics are covered by O. W. Richardson and C. L. Fortescue. The engineering side is not so prominent here as in Vol. I, but the physicist will find all he wants in such articles as those on Dynamo Electric Machinery, Wattmeters, Transformers, and, of course, Telegraphy and Telephony.

The manner in which the Dictionary is produced is admirable; the only practicable improvement which suggests itself is that the numbers and headings of the paragraphs should have been printed in heavier type: they are not now as readily distinguishable as they might have been in the interests of quick reference. The editor's task in the selection of articles and distribution of space must have been heavy and difficult; he has accomplished it with notable fairness and success. The cost of the volumes is considerable, but quite reasonable in view of the quantity and quality of their contents. Those whose library of physics books has yet to be formed will find its size and cost greatly diminished by the inclusion of the Dictionary. It will prove indispensable in all laboratories whether devoted to teaching, research, or the routine of industry; as a time saver it will be invaluable to all engaged in lecturing on the subject, and the writers of our future textbooks will find it a mine of extraordinary richness. The publishers are to be congratulated on their enterprise, and on the addition of yet another item to their already long catalogue of science classics.

D. O. W.

**Within the Atom: A Popular View of Electrons and Quanta.** By John Mills, Fellow, American Physical Society. [Pp. xiii + 215.] (London: George Routledge & Sons, Ltd. 6*s*. net.)

It is often difficult for one conversant with scientific terms and ideas to assess the value of a book which is written for the general reader. In this case the difficulty is not so great as usual, partly because the author makes exceptionally extravagant claims in the preface. The reader, we are told, need have no previous knowledge of electricity, mechanics or chemistry, yet on page 4 reference is made to "the familiar facts of electricity." Such a reader, we have no hesitation in saying, would be completely at sea with many of the terms and concepts introduced, even after consulting the glossary at the end of the book. (It may be mentioned, in passing, that an electrometer is defined as "an instrument for measuring an electric charge.")

Yet for one who has some knowledge of the subject but no opportunity of consulting original papers the book serves a useful purpose, as it gives a comprehensive account, without mathematical analysis, of current views of the structure of the atom and of the nature of energy. At times the exposition fails to carry conviction and interest through the omission of details. But in so small a space it was impossible to include everything, and the book gives up-to-date information over a wide field.

G. A. S.

**Some Physico-Chemical Themes.** By A. W. Stewart, D.Sc. [Pp. xii + 419, with 5 plates and 37 diagrams in the text.] (London: Longmans, Green & Co. Price 21*s*. net.)

This volume consists of a series of essays on Physical Chemistry, written in an especially interesting and vivid manner. The author does not cover the whole field of physical chemistry in these essays, but makes a selection from some of the more interesting branches of the subject, which have been arranged so as to give a connecting thread of interest throughout the book. In the development of his themes the author has no hesitation in making new tracks for himself in the unknown land between related sciences.

Some of the chapters, that on pseudo-acids and portions of the other essays, have appeared before in the author's textbook, *Recent Advances in Physical and Inorganic Chemistry*. The essay on the development of the periodic law is especially good; in this, and in subsequent chapters, he collects together, in a very readable form, information relating to the periodic table which has hitherto been scattered through the literature, and in many cases has been inaccessible to the ordinary student of chemistry. In the preface emphasis is laid on the necessity for a wider study of the physical chemistry of organic compounds, and, in some of his themes, he devotes especial attention to this branch of chemistry.

The author, however, has his "crochets"; he dislikes "Ostwaldian" physical chemistry, with the result that the chapter on the theory of indicators is entirely lacking in the physico-chemical aspect; he is unfair to Werner's theory in the chapter on chemical affinity; he hastily condemns the Bohr theory, which he considers as utterly worthless from the point of view of chemistry and radio-chemistry. It is to be regretted that the author does not hold a more even balance between the conflicting theories of modern chemistry. Objection may be made to the statement on p. 121 that colour production in salts is "absolutely independent of ionisation"; according to modern views on the structure of crystals ionisation is a characteristic feature of salts in the solid state.

With the aid of this book, the student should be able to grasp the trend of physico-chemical research at the present day, and, since the book provides its own antidote, will find Dr. Stewart's independence of view very refreshing and stimulating.

A useful bibliography is appended.

W. E. G.

**The Emission of Electrons from Hot Bodies.** By O. W. Richardson, F.R.S. Second Edition. [Pp. vii + 315.] (London: Longmans, Green & Co. Price 16*s*. net.)

This is the second edition of a very well-known monograph, the first edition of which appeared in 1916. The author has, of course, a world-wide reputation as a pioneer and an indefatigable investigator in the subject of thermionics. The work still holds the field as the most complete exposition of the subject in book form. There have been considerable additions made to the first edition, and parts have been rewritten to bring the subject-matter up to date. For example, a description of the Knudsen radiometer gauge, which is displacing the McLeod for some purposes, is given in Chapter I. Some new theoretical investigations bearing on the equilibrium of electron atmospheres, due to von Laue, appear in Chapter II. Quite a body of new information is given concerning the temperature variation of electronic emission.

The book still remains an indispensable companion for those whose interest in thermionics extends beyond the sketchy acquaintance of the textbook reader.

J. R.

**La Physique Théorique Nouvelle.** Par JULIEN PACOTTE. [Pp. vii + 182.] (Paris: Gauthier-Villars. Price 12 frs.)

THIS is a very ambitious book. It attempts, according to Borel (the writer of the preface) "to resume, in a book of modest dimensions, without mathematical equipment the totality of theories which constitute the new theoretical physics." We fail to see where the book lacks mathematical equipment. For the most part, in treating mathematical physics, the book uses the mathematical equations "written in words" (*vide* p. 65). To those interested the equations written in symbols would make the reading easier. (Compare, for instance, the plan adopted by Whittaker in his *History of Ether and Electricity*.) The general theory of relativity seems to be too recent to be included in the "ensemble."

To those interested in experimental physics Chapter IV would appeal most.

On the whole the book is very sound.

J. R.

**Philosophy and the New Physics.** By L. ROUGIER. Translated from the French by M. MASIUS. [Pp. xi + 159.] (Philadelphia: Blakiston's Son & Co.)

THE book deals with a metaphysical problem which existed half a century ago, when natural phenomena were interpreted in terms of two groups of substances—matter which possessed weight, and certain fluids or so-called fluids (caloric, electrical and magnetic, etc.) which were devoid of weight.

The problem was this—how was it possible for the imponderable to affect ponderable matter? There seemed to be some link missing in this method of interpretation.

The development of physics and physical theories since that time has been effective in removing the problems, as now everything is interpreted in terms of one agent, energy—with the possibility of existing in one of two forms—that which we ordinarily call matter, and that which we call radiation, but both similar in nature and possessing inertia.

This development is very carefully traced, the experimental data upon which progress depended being indicated clearly, step by step.

Initially we get the attempts to explain all actions in terms of matter, even action at a distance. Then the idea of the space surrounding matter playing a part, originated by Faraday, brought out the localisation of energy in the dielectric medium rather than in the matter itself. Later the study of cathode rays, bringing out the fact that their inertia is wholly electromagnetic, and the researches revealing the ubiquity of the electron naturally seemed to lead to the conclusion that all matter is really energy. The pressure of radiation also emphasises the fact that radiant energy possesses inertia.

The author gives an extremely good general survey of this field, and passes on to show the effect of Einstein's relativity principle and Planck's quantum hypothesis on the interpretation of phenomena.

The book is an extremely good introduction to an understanding of these theories. References to all important original papers are given, and a bibliography of literature connected with the subject is put at the end of the book, but there seems to be a scarcity of reference to English works.

J. R.

**Rayonnement et Gravitation.** Par Félix Michaud. [Pp. viii + 61.] (Paris : Gauthier-Villars. Price 6 frs.)

This is an intensely interesting book. The author points out that it is difficult nowadays to decide what is simple. Many customary concepts have only the appearance of simplicity. It is best therefore, in attempting to explain physical facts, to adopt a suitable starting-point, and Radiation is chosen as such.

The first part of the book deals with the optics of bodies in movement. The experimental facts to be explained are clearly stated. Their explanation is next considered in an order which differs considerably from the usual one. The only postulates used in the first part of the book are the energetics of Radiation and the Principle of Relativity restricted to uniform translation.

Chapter V, dealing with transmission of light in different media, is characteristic of the author's lucidity. The assumptions are clearly stated and the deductions are in places elegant.

On the basis of Radiation the second part of the book builds up Gravitation, Inertia, Cohesion, Capillarity, Electricity and Magnetism, the last-mentioned, however, only in an outline fashion.

In Chapter VI we get a neat explanation of photophoresis. In the same chapter gravitation phenomena are stated to have their origin in the capability of matter to absorb a radiation filling all space. The energy of radio-active changes receives here an interpretation in terms of radiation.

In later chapters physical interpretations are given to the inertia and weight of radiation, the anomaly of the perihelion of Mercury, and the dependence of mass on velocity.

J. R.

**General Physics,** and its application to industry and everyday life. By Edwin S. Ferry, Professor of Physics in Purdue University. [Pp. xvi + 732, with 600 figures.] (New York: Wiley & Sons ; London : Chapman & Hall, 1921. Price 24*s*. net.)

Our admiration for American textbooks in the past has been restricted to those dealing in an elementary way with everyday physics or, rather, everyday science. Books above this standard have generally contained peculiarities (to put it politely) in their treatment of fundamental principles which has made it impossible to recommend their use in this country. Professor Ferry's textbook is not subject to this disadvantage, and he has to be congratulated on having written a novel—a refreshingly novel—textbook of physics of a standard rather higher than that demanded by the intermediate examination of the English Universities. With the orthodox division of the subject: Dynamics and General Properties of Matter, Sound, Heat, Electricity, Light, the author has combined a quite unorthodox disregard of the limits usually imposed by the examination syllabus with a novelty and thoroughness of exposition, illustration, and example which is as unusual as it is welcome. There are about 1,000 problems for the student to solve —many of them quite new to the reviewer—including about 700 numerical examples at the end of the book to which answers are given.

We should like to recommend the book for ordinary class use : we can do so for those cases in which an external examination is not in immediate view. We are quite sure that no teacher who adds it to his collection will regret his purchase : or forget that it is there !

D. O. W.

## CHEMISTRY

**Introduction to General Chemistry.** By H. COPAUX, translated by HENRY LEFFMANN, A.M., M.D. [Pp. x + 195, with 30 illustrations.] (Philadelphia: P. Blakiston's Son & Co.).

THIS is a textbook presenting the fundamental principles of chemistry in a compact form. The atomic theory, methods of classification of the elements, theories of dilute solution, and chemical affinity are dealt with in an elementary manner. The book is not entirely free from vagueness; thus, on p. 93, it is stated that "$H_2SO_4$ becomes $H_2^+$ and $SO_4^-$," without any regard being paid to the magnitude of the charge on the ions, and on p. 109, "Glass is a solid solution, being amorphous mixtures of different chemical compounds," making use of the term "solid solution," which is better retained for crystalline substances. Otherwise, the subject matter is presented in a clear and simple manner, and should be a useful volume to those who wish to grasp the first principles of physical chemistry.

W. E. G.

**The Chemistry of Combustion.** By J. NEWTON FRIEND, D.Sc., Ph.D. [Pp. vii + 110, with 24 figures.] (London: Gurney & Jackson. Price 4*s*. net.)

THIS monograph, a volume in the series edited by A. C. Cumming, D.Sc., was the outcome of a course of lectures to chemical students at the Birmingham Municipal Technical School. It is a very useful summary of the research work, carried out very largely in this country, on the combustion of hydrocarbons. The author gives a very clear and concise account of the theories of combustion, and the experimental work on ignition temperatures, limits of inflammability of gaseous mixtures, the velocity of propagation of flame in gaseous mixtures, and on surface combustion.

W. E. G.

**Chemistry of Radioactive Substances.** By A. S. RUSSELL, M.A., D.Sc. [Pp. xi + 169.] (London: John Murray. Price 6*s*. net.)

THE importance of radioactive elements for the development of modern physical theory has directed attention from these substances as chemical atoms. Although the general reader of science is familiar with the nomenclature of the radioactive elements, their atomic numbers and the physical aspects of their disintegration, he has had little opportunity of acquiring knowledge of their chemical behaviour. This need has now been met by the author's fascinating book on the chemistry of radioactive substances. This volume, while not neglecting the purely physical aspects of radioactive disintegration, gives an account of the chemical properties of the radioactive elements and of the technique of their methods of preparation and separation. An interesting chapter is included on the application of radioactive substances as indicators in analysis, and for the determination of physical constants, such as the solubility of sparingly soluble salts, etc.

This book is not intended as a monograph, although the author's main sources of information are given. It will be extremely valuable to the student, teacher, and general reader.

W. E. G.

**Proteins and the Theory of Colloidal Behaviour.** By JACQUES LOEB. [Pp. xi + 292, with 1 plate chromo.] (New York and London: McGraw-Hill Book Company, 1922. Price 15*s*. net.)

THE modern development of colloid chemistry has followed from the conception suggested first by v. Naegeli in 1858, three years later by Graham, and brilliantly confirmed by Siedentopf and Zsigmondy in 1903, that the ultimate particles of bodies in the colloidal condition are aggregates. It seemed improbable that the stoichiometrical laws of classical chemistry should apply to a state in which specific surface appeared to be a predominating factor. Consequently, colloid chemistry has been treated as a separate subject in which the classical laws were replaced by Freundlich's empirical adsorption law and the Hofmeister series. Exceptions to the adsorption law were found, and it might have been thought significant that every property of true solutions is affected by series of anions and cations similar to those that have played so important a part in the theory of colloids. But suggestions made from time to time that colloids should not be regarded as exempt from the laws of chemistry have not been well received.

The book before us is revolutionary in character. Prof. Loeb gives an account of a brilliant series of experiments which indicate that the amphoteric proteins combine stoichiometrically with acids and alkalies. The Hofmeister series is then explained by the fact that different acids, alkalies, and salts have different effects on the pH of protein solutions. When this is allowed for, the only effect is that of valency, and all the properties of proteins, their osmotic pressure, swelling, P.D. viscosity, and stability, can be explained mathematically on the basis of the Donnan equilibrium.

As the result of v. Weimarn's experiments we have abandoned the division of substances into two separate classes of crystalloid and colloid. Now it seems incorrect to discriminate between crystalloidal and colloidal solutions, or to regard the science of colloids as a water-tight compartment of physical chemistry.

On p. 46 the argument is a little difficult to follow. And on p. 131 it would have been clearer to use the term $\frac{y}{x}$, as on p. 125, instead of $\frac{x}{y}$. Otherwise, as would be expected, the book is clearly written and practically free from misprints. It is a work that will survive much criticism and must be read by everyone seriously interested in colloid chemistry.

S. C. B.

**Chemistry and its Uses.** A Textbook for Secondary Schools. By W. McPherson and W. E. Henderson. [Pp. viii + 447, with 260 illustrations.] (London and New York: Ginn & Co. Price 7*s*. 6*d*. net.)

This is a typical American secondary-school textbook, and as such has a special interest for the English secondary-school teacher. The point of view from which the subject is dealt with is very different from that of the average English school teacher, who tackles his subject either from the academic point of view as a pure science, or from that of the educationist, as a means of mental training, or perhaps most commonly from a compromise between these two. The textbook before us, however, has obviously been written with a view to giving the student some knowledge of chemical processes in their relation to daily life, a characteristic attitude of all American school teaching, and, in some degree, one from which we English teachers can well afford to learn. For this reason we welcome this book and strongly recommend it to English school teachers of science. It might well be used as a supplementary reader in the upper classes, and if the book served no other purpose, it would at least give added interest to the study of the subject by the pupils themselves.

One notices also, in the exercises particularly, the tendency in the American schools to make the pupils study their textbooks for themselves, without expecting so much aid from their teachers. The illustrations are very good and will prove of great value in explaining the modern developments of applied chemistry.

W. C. B.

**The Chemical Examination of Water, Sewage, Foods, and other Substances.** By J. E. Purvis, M.A., and T. R. Hodgson, M.A. Second and enlarged Edition. [Pp. v + 346.] (Cambridge University Press, 1922. Price 20*s*. net.)

The first edition of this book is too well known to those interested in the subject with which it deals to require any detailed description or commendation. In the new edition the book has been enlarged to the extent of over 100 pages. Nearly one-third of the volume is devoted to water, sewage, and effluents, together with an increased number of typical analyses, which should materially assist students in interpreting their analytical results; due attention is also given to the composition of sea water and its influence upon the decomposition of sewage, a subject to which one of the authors has devoted special study. New chapters dealing with the analysis of meat extracts and products and with toxicology have been added; the latter, as stated by the authors, is put forward merely as a basis upon which a student can work, and with the small amount of space devoted to it this is all that can be claimed for it. For the rest, the book has been brought up to date in a manner calculated to ensure its continued and well-merited success.

**Physico-Chemical Problems relating to the Soil.** A General Discussion held by the Faraday Society. Reprinted from the *Transactions of the Faraday Society*. Vol. xvii, Part 2, 1922. [Pp. 217–369.] (Price 10*s*. 6*d*. net.)

The Faraday Society has for some years followed the excellent practice of holding General Discussions, at which papers, followed by discussion, are presented on some aspect of Scientific Work coming within the purview of the Society. The volume before us contains the proceedings of the twenty-ninth of these meetings, and will be welcomed by all agricultural scientists. There are at the present time very few branches of science unrepresented in agricultural research, and the sixteen papers in this volume afford a good idea of the progress already made, and the difficulties still to be overcome, in our knowledge of the physico-chemical properties of the soil.

The papers are grouped into five sections: Introduction, and general papers, (2) Soil Moisture, (3) Organic Constituents of Soil, (4) Adsorption Phenomena, (5) Colloidal Phenomena. That these divisions should be regarded, in the main, as only a convenient way of grouping the papers for the purpose of discussion, appears from the general survey of the subject contributed by Dr. Russell. The soil is a system made up of mineral fragments of all sizes, organic matter derived from past generations of plants and animals, and moisture containing a number of substances in solution. Some of the constituents of this system have marked colloidal properties, and the presence of micro-organisms and the constantly fluctuating meteorological conditions introduce additional complexities. The soil investigator, therefore, is faced by the problem of disentangling one or two factors from a large number of interdependent ones; he also has the further difficulty that many of his problems are not necessarily made easier of solution by replacing the soil by a simpler material, such as china-clay, owing to the degree of artificiality then introduced. This is clearly brought out in the discussions, especially those following sections 3, 4 and 5, in which Dr. W. R. Ormandy took a prominent part. These discussions largely dealt with the effects of the clay fraction and the organic material in soil, and one of the merits of Dr. Ormandy's critical comments was to focus attention on some problems where a comparison of soil with substances such as china-clay would be very desirable. A large amount of information has been accumulated on the behaviour of clays used in the ceramic industry, and the clay fraction in soils has been studied by many workers, but the points of similarity and dissimilarity between these materials (to say nothing of the different meanings attached to the same word in the two industries) are at present almost unexplored.

In this connection it is instructive to compare Dr. Mellor's paper on the plasticity of clays with those of Mr. Comber on the mechanism of flocculations, and Mr. Morrison on the formation of the hard layer, known as a "pan," in soil.

Returning to the sections in which the papers are grouped, the section dealing with soil moisture contains an introductory paper by Mr. B. A. Keen, who discussed the significance of the various divisions and equilibrium points recognised in the soil moisture by American investigators with special reference to the method of the freezing-point depression. Prof. Odén contributed a note on the hygroscopicity of clay in which he showed that this quantity depended not only on the surface area of the clay particles, but also on its chemical nature and constitution. Two papers are also contributed in the section by American investigators—on the soil solution in relation to the plant, by Prof. Hoagland, and on osmotic phenomena, by Prof. Shull. The former deals with the relation between the concentration of salts in the soil solution, determined by analysis of water extracts and other means, to the growth of plants ; the latter paper is devoted to various theories of the osmotic action of the root hairs in the passage of water from the soil into the plant.

In the concluding paper of this section Dr. Hackett gives an account of experimental work on the ascent of liquid through granular media, in which it is shown that the laws of capillary flow are obeyed for the initial rise which takes place in the tube-like spaces between sand grains. This comparatively rapid initial rise is followed by a slow ascent, which is apparently not explained by the theory of capillary flow.

A number of the essential properties of soil are conferred upon it by the organic matter present. These properties are discussed by Mr. Page in the introductory paper to section 3. Prof. Odén gives a summary of his important investigations on humus, in which he has demonstrated the existence of humic acid, and thrown considerable light on the question of the origin and cause of soil acidity. Dr. Salisbury discussed from the ecological standpoint the vertical distribution of soil acidity in soils, and showed that under conditions of undisturbed natural vegetation, the acidity decreased from above downwards.

The opening paper in the section dealing with adsorption phenomena is by Mr. Fisher, who critically discusses the application of the empirical adsorption equation to the reactions between soil and some inorganic substances. Mr. Crowther deals with some aspects of soil acidity, such as the methods for measuring the hydrogen-ion concentration of soils, and the action of neutral salts on acid soils ; Mr. Morison discusses the causes of pan formation, which appears to be due to the translocation of colloidal material from the surface layer of soil and its subsequent coagulation at a certain depth, where it has a cementing effect on the soil particles and produces a hard impervious layer.

In the final section, Prof. Odén describes his method of mechanical analysis, by which he obtains a curve showing the distribution of the weight (or number) of particles corresponding to given radii. Mr. Comber deals with mechanism of flocculation, and brings forward evidence to show that the clay fraction can be regarded as having a siliceous protection, which impresses emulsoid properties on the clay.

The *verbatim* report of the discussions following the papers has already been mentioned. It adds much to the value of the papers themselves.

B. A. K.

## GEOLOGY

**Man as a Geological Agent.** By R. L. Sherlock, D.Sc., A.R.C.Sc., F.G.S. [372 pp.] (London: H. F. & G. Witherby, 1922. Price 20*s*. net.)

There is nothing intrinsic to the science of geology to preclude the study of the part played by man in the development of the earth's crust, but it has been tacitly agreed to term this action artificial and dismiss it in as few words as possible. The author points out that a difference of degree rather than kind can be considered to exist between man's part and that of other rock-forming animals in support of this statement. However, there is a difference in that man's work is, or tends to be, always progressive, and new problems of bridling Nature are continually being solved. The book is chiefly descriptive, but a few words to refute the suggestion of man's opposition to natural forces border on the philosophical.

Quality, quantity, and permanence are the three chief factors discussed. Man is a rock-destroyer and a rock-builder, but more far-reaching are the results of his work in altering drainage and even climate. As a rock-destroyer, man has brought up from mines vast quantities of material, incidentally affecting the surface by subsidence, while his activities in excavation at the surface are also familiar to all. There is something more interesting, however, in the accumulation of artificial products which the author compares with natural rocks in a chapter sure to appeal to every type of reader. Man's interference with drainage and sea coast is shown to have both a positive and negative effect on erosion, with a possible net result of surface gain. Deforestation, improved drainage, and increased carbon dioxide production all tend to raise the temperature, and similar arguments might be employed to explain former geological changes of temperature.

The author has taken much trouble to estimate the amount of man's activity, but the order of magnitude is all we can hope for or indeed require. The methods of obtaining statistics are both interesting and instructive, the figures used being those for London and England, suitable and representative localities. The results, dependent chiefly on population and engineering industries, show man's action to be irregular, much greater than natural changes and most resembling glacier action.

Finally, since the direction of human action is constantly changing, man tends to destroy his own work. "Man's most permanent memorial is a rubbish-heap," says the author, referring, of course, to the made-ground forming a city's foundation, "and even that is doomed to be obliterated."

Apart from its interest as a geological work, the subject is one of economic and philosophical value, and the book can be well recommended to the general reader; the middle course between the scientific and popular treatment has been adopted with advantage. All have read of the influence of environment on man, but the converse forms a novel and interesting study.

Edgar D. Mountain.

**Earth Evolution and its Facial Expression.** By W. H. Hobbs. [Pp. xvii + 178, with 6 plates and 84 figures.] (New York: The Macmillan Co., 1921. Price 15*s*. net.)

Prof. Hobbs has added another to his fascinating expositions of geologica science in his book on *Earth Evolution and its Facial Expression*. He starts from the view that since the planetesimal hypothesis of the origin of the earth has now largely replaced the nebular hypothesis of Kant and Laplace, the foundations of geology need to be rebuilt in accordance with the new ideas.

The book deals with certain fundamental problems of theoretical geology, connected with the growth of continents and mountains, and the impress made by these processes upon the surface lineaments of the earth. The planetesimal hypothesis does not provide for any molten igneous masses, save the unsatisfactory "radial threads" of Chamberlin. We begin to part company with Prof. Hobbs, however, when he derives pockets of igneous magma from the fusion of shale due to relief of pressure in the crust consequent upon earth movements. He relies on a rather specious resemblance in chemical composition between the average igneous rock and the average shale, neither of which are very satisfactory entities. The greatest bodies of igneous rock are the enormous basalt floods which cover areas of the order of hundreds of thousands of square miles in various parts of the world, and the huge granodiorite or granite batholiths of Cordilleran regions, neither of which have the slightest affinity to, nor could have been derived from, fused shale. Nor does the theory explain why the basalt floods are associated with major vertical block movements of the earth's crust, and the acid batholiths with relatively narrow belts of folding.

The next section of the book deals with the changes of figure through which the earth has passed. Prof. Hobbs supports the theory that the disposition of the main earth features is dependent upon tetrahedral deformation. In this the greatest strains occur in the zones separating rising and sinking sectors; and this leads to the consideration of the present-day regions of greatest change, indicated by the distribution of earthquakes, volcanoes, and young fold mountains. In this connection an instructive contrast is developed between the "live" Pacific and the "dead" Atlantic coasts of the two Americas. The uprise of the Cordilleras bordering the Pacific Ocean is held to be due to lateral thrust from the subsiding ocean floor. It would be interesting to learn whether all this could be squared with Wegener's theory of continental drift, but Prof. Hobbs does not mention Wegener.

In opposition to the prevalent Suessian conception, Prof. Hobbs develops the view that underthrust from sinking areas, rather than overthrust from rising land masses, is responsible for the overturning of folds, the accurate outlines of fold mountains, and their tendency to present an apparently advancing front towards adjacent sinking areas, generally oceans.

Remaining chapters have the intriguing titles, "The Patterns of the Facial Wrinkles," "The Design of the Fracture Marquetry," and "Lava Composition in Relation to Earth Physiognomy." Notwithstanding one or two points in which theory has overrun corroborative facts, Prof. Hobbs has produced an extremely suggestive and thought-provoking book, which will help the advanced student and research worker to formulate more clearly his own conceptions of the greater earth problems.

G. W. T.

**Graphical and Tabular Methods in Crystallography.** By T. V. Barker, M.A., B.Sc., F.C.S. [Pp. ix + 152.] (London: Thomas Murby & Co. Price 14*s*. net.)

The geometrical or goniometrical study of crystals, which forms the subject-matter of this book, has not often been treated from such a utilitarian point of view. Mineralogists have often spent hours trying to identify faces hitherto unmentioned in the standard works, but although collected data of this description may serve their purpose, we have now to consider merely a means of identification in view of the ever-increasing number of crystalline organic compounds.

The author gives a critical selection of exact graphical methods found by experience to be most adequate, with a brief theoretical explanation, and finally outlines his ideal system of investigating and describing a crystal. Fortunately, perhaps, the details are not original, for the suggestions are based chiefly on well-known methods which, however, have never been generally adopted. We are indebted to the author for many abstracts from the work of E. S. Fedorov which have not yet found their way into easily accessible literature.

In the same way the protractor advised embodies the principles of those of Hutchinson, Fedorov, and Penfield, and although rather clumsy and complicated, serves the purpose of several ordinary auxiliaries. However, habit is too strong for us to expect any but youthful enthusiasts to adopt its use.

The principles of stereographic and gnomonic projections (including the very important Angle-point or Winkelpunkt) are set forth briefly, and a rather arbitrarily chosen set of problems and examples appended. The relation between indices and reticular densities referred to as Mallard's Theorem just borders on crystal structure. Once again the advantages of gnomonic over stereographic projections and of two (and three) circle over one circle goniometry are vindicated; two circle goniometry is solid geometry compatible with solid figures and naturally adapted for projection, while the gnomonic projection is superior to the stereographic for determination of indices and crystal drawing.

In computation the cotangent form of the Anharmonic Ratio, and particularly the Harmonic Ratio, is employed rather than the more usually adopted sine form and a set of tables added, like the Hutchinson slide rule, to solve the formula $\frac{\tan x}{\tan y} = \frac{p}{q}$. Its application is abundantly demonstrated, and an especially interesting case is the rhombohedral system. Considering the nature of the book some of the small type print on the accuracy of graphical methods might have been given greater prominence.

The chief points of the new system turn on a preference for fundamental measured angles rather than theoretical calculated values of axial ratios and angles—a suggestion justly vindicated by the anorthic system. An outline of standard methods for investigation and description is given which should prove invaluable as a groundwork and guide to future crystallographers, and though new suggestions of systematic methods take long to become universally adopted, the book is based on sound practical lines.

EDGAR D. MOUNTAIN.

**Geology of Non-metallic Mineral Deposits other than Silicates. Vol. I. Principles of Salt Deposition.** By AMADEUS W. GRAGAU, S.M., S.D. [Pp. xvi + 435, with 125 text figures.] (New York: The McGraw Hill Book Co., Inc.)

THIS book is the first volume of a treatise which is intended to deal with those non-metallic minerals usually designated as "salts," the term being used in a sense sufficiently wide to include the halides, sulphates, nitrates, phosphates, carbonates, borates, and so forth. An attempt is made, on the basis of known geological relationships combined with results of synthetic work in the laboratory, to elucidate the conditions of formation of such deposits. The amplification of field work by laboratory investigations during the past forty years has greatly increased our knowledge of the geology of such salts; for example, the classical work of Van 't Hoff and his colleagues, based on phase-rule investigation of the particular substances concerned, has yielded a fund of information concerning the origin of oceanic salt deposits.

The volume under review is confined to an examination of the principles of the deposition of these salts, especially with reference to those now forming, the application of these principles to the problems presented by the older deposits being deferred to a later volume. The first two chapters are of an introductory nature, the first one treating, in an elementary way, the chemistry of the salts, while the second gives an account of the characteristics and occurrences of the more important salts. The inclusion, in the latter, of such terms as "halo-carnallite" or its synonym "carnallitite" for the entectic mixture of halite and carnallite, is to be deprecated; this entectic mixture is not a salt, while the subject is already overburdened with a vast nomenclature which includes many unnecessary names.

Five chapters are devoted to the problem of sea salts, and they include accounts of the synthetic work on the subject, of chemical and organic deposition in nature and the parts played by organisms therein, of the origin of deposits formed under marginal conditions and also those formed in closed basins, and finally of the so-called " cyclic " salts such as those of Sambhar Lake. The discussion of the physical chemical aspect of the subject is somewhat inadequate and much of the space which is given up to illustrations of the organisms responsible for deposition would have been better utilised in a further elaboration of the synthetic work.

The remainder of the book is occupied by accounts of terrestrial salts, of those of igneous origin, and of those formed by metamorphic agencies. One chapter is devoted to that important group of salts which owe their origin to the concentration of sea salt occluded in marine sediments during their deposition ; on the basis of Lane's term " connate water " such salts are termed " connate sea salts." The nitrates, the phosphates and the complex borate salts are each considered in separate chapters.

Although the book, as a whole, suffers to some extent from the author's obvious intention to make it a students' textbook, it may be said to give a clear and readable account of the subject. This is especially the case with those parts of the text which are definitely geological ; the treatment there is much more complete than in the more chemical portions where there is a tendency to omit detail. The illustrations, especially the sketch-maps and sections, are very useful, but the references, though abundant, might be more complete ; there is a curious lack of system in the method of giving the references. An elaborate index is appended.

A. S.

## BOTANY

**The Naturalisation of Animals and Plants in New Zealand.** By The Hon. G. M. Thomson, M.L.C., F.L.S. [Pp. x + 607.] (Cambridge : at the University Press, 1922. Price 42*s*. net.)

The introduction and subsequent establishment or failure of plants and animals in New Zealand affords a unique opportunity for the study of these aspects of geographical distribution, since the process has for the most part taken place during a period sufficiently recent to permit of investigation.

Mr. Thomson's work is a presentation of the ascertainable data embodying the results of painstaking research, and the 361 pages recording the actual facts respecting animal introductions, and the 139 pages devoted to the plants, constitute a mine of information from which the student of problems connected with establishment and survival can quarry.

In respect to Flora and Fauna alike the process of introduction has been an epitome of the effect of human interference on the balance of power as exemplified by wild Nature.

Many of the species owed their introduction to the numerous acclimatisation societies of the 'sixties and the early immigrants desirous of having around them the animals and plants of the homeland. Not till too late was the lesson learnt that the balance of Nature cannot be disturbed with impunity. The rabbit, at first difficult to establish, developed into a plague, the sparrow became a feathered pest. Similarly in the vegetable world the blackberry and the sweet briar, both intentionally introduced, became noxious weeds no less harmful than the thistle *Cnicus arvensis*.

Cats, ferrets, stoats, and weasels have all been introduced to keep the rabbit plague in check, whilst the goat was encouraged with a view to combating the growth of blackberries. Each in turn has become itself a nuisance, whilst in some cases the pest which it was intended to destroy has been neglected for another source of food.

No less interesting than the vigorous development of these and other species, such as the blackbird, the starling, gorse, broom, ragwort, etc., is the story of their vicissitudes and the interaction of one species with another.

Several instances are cited of the diminution of native animals by reason of the increase of introduced species, but with respect to plants the author supports the contention of Cockayne that the native Flora is quite capable of withstanding the invaders except where the natural conditions have been altered by the influence of man. The phenomenon of the frequency maximum followed by a decline in numbers and vigour, so often quoted in respect to the *Elodea* pest in this country, would appear to have had its counterpart in the history of *Cnicus lanceolatus* in New Zealand and also of the rabbit within certain areas. The latter, which was formerly a pest in both wet and dry districts, has now disappeared from some of the colder and damper regions.

The repeated introductions which failed have also their lessons to teach, and indeed the problems upon which these data bear are amongst the fundamentals of biological distribution. Some of these are considered in the two chapters on the subjects of the interaction of endemic and introduced Faunas, and the alteration of the Flora since European occupation.

The final chapter on Legislation is an interesting, and at times humorous, commentary on the gradual education of public opinion, whilst the laws themselves are a useful index of the increasing seriousness of the pests concerned.

As already indicated, the major portion of this work is concerned with the presentation of what is known respecting the history of each species of introduced animal and plant: a catalogue of facts for which biologists owe no small debt to the author, and which the student should place upon his shelf to digest at leisure. E. J. Salisbury.

**Basic Slags and Rock Phosphates.** By George Scott Robertson, D.Sc., F.I.C., with a Preface by Edward J. Russell, D.Sc., F.R.S. Cambridge Agricultural Monographs. [Pp. xvi + 120, with 8 plates.] (Cambridge: at the University Press, 1922. Price 14*s*. net.)

At first sight there would appear no obvious relation between a change in the method of making steel, and the manurial requirements of hay and pasture fields. There is, however, a very real connection; the slag which separates from the molten metal was shown, forty years ago, to have valuable fertilising properties, and its use—under the name of basic slag—rapidly extended, largely owing to the demonstrations of its beneficial properties at the experimental station at Cockle Park, Northumberland, and elsewhere. Its use has been almost exclusively confined to grass land, although in certain districts, notably in Essex, it is employed instead of superphosphate, on arable land which is deficient in calcium carbonate. The characteristic of basic slag from the agriculturalist's standpoint is its content of phosphate, especially phosphate in an easily soluble form. The older type of slag resulting from a modified Bessemer process was very satisfactory in this respect. Unfortunately for the farmer, the Bessemer process is being rapidly displaced by the basic open hearth method, and the slag produced in this process has usually a lower content of phosphate, which is in a less available form than that produced by the older process.

There are further difficulties; slag is a waste product, of little if any interest to the steelmaker, who is not likely to make any alterations involving extra expense in his methods of manufacture for the sake of improving the agricultural value of this waste product; the supply of slag depends entirely on the demand for steel, and is insufficient in normal years for the potential demands of agriculture, which have been put by the best authorities at nearly 1,000,000 tons per annum.

Dr. Scott Robertson's monograph appears, therefore, at an opportune time. He has tested, over a period of several years, a number of different types of slag, and has also included various mineral or rock phosphates. The experiments have been done at a number of centres in Essex, on boulder clay, London clay, and chalk soils. Inspection of the tables and diagrams clearly shows the beneficial effects on the yield of hay of all the forms of phosphate used. There were, however, two centres where the increase was not significant. In one case the soil was comparatively rich in phosphate to begin with, and deficient in potash, and in the other the potash content was also low, and the conclusion is drawn that the lack of potash was acting as a limiting factor to production. In cases where no such limitation comes in, the highly soluble slags gave better results in dry seasons than less soluble slags or mineral phosphates, but in wet seasons there was less difference. In view of the low average rainfall in Essex, it seems reasonable to conclude that over the greater part of the country rock phosphate—especially that from North Africa—will be a suitable substitute for the disappearing high-grade basic slags. There is one probable restriction to this conclusion. Dr. Scott Robertson, during his frequent inspections of the experimental plots, concluded that rock phosphates are slower than basic slag in their action during spring and early summer. Hence for conditions when the harvest is early, higher soluble slags should be used, but if the crop grows until the latter end of July the difference largely disappears.

Besides this increase in bulk of the herbage, the change in its quality has also been examined. The characteristic effect of phosphates in increasing the amount of clovers present is accompanied by an increase in the better type of grasses, probably due to a direct fertilising action. This latter effect was noticed at one centre where the clover did not markedly respond until the following year. There are considerable fluctuations in the amount of clover from year to year, the causes for which are not clear, and could profitably receive further study.

A very interesting set of moisture and temperature determinations shows the beneficial indirect effect of phosphates in preventing the soil from cracking, and in keeping down the temperature during dry, hot spells. Some observations on the effect of phosphates on the accumulation of nitrates in the soil, both in the field and in pots, are also given, which indicate that at certain periods during the season there is a greater accumulation of nitrates in the slag plots than in the untreated.

The monograph concludes with a section on the action of basic slag on the acidity of the soil, in which the failure of the clover plant at Cockle Park is discussed and contrasted with the failure on some pastures in Essex during the dry season. In the former case phosphate appears to be the limiting factor, and in the latter case the principal cause is the lack of available potash.

The energy and zeal of Dr. Scott Robertson will be appreciated by all those familiar with the large amount of work inseparable from the efficient conduct of scattered field experiments, and the information given in the monograph should prove most useful to agricultural advisers and farmers generally.

B. A. Keen.

**Agricultural Economics.** By James E. Boyle, Ph.D., Extension Professor of Rural Economy, College of Agriculture, Cornell University. [Pp. ix + 448.] (London: J. B. Lippincott Co., 1921. Price 12*s*. 6*d*. net.)

As Malthus realised more than a century ago, the food supply of a country determines both the extent of its population and the happiness of the people comprising it. The food supply itself is determined by agriculture and by other industries such as transport and storage closely connected with it economically. The subject of Agricultural Economics is thus one which, taken in a wide sense, is of very considerable economic importance in the welfare of nations, and a work upon it is therefore one which should be of general interest as well as of profit to those intimately connected with agriculture. Such a book is Prof. Boyle's *Agricultural Economics*. A wealth of information on the various aspects of the economics of agriculture is crammed between the covers of this book, the numerous problems of the subject are clearly indicated and discussed, while the provision of lists of references for further reading adds greatly to the value of the work.

W. S.

**Germination in its Electrical Aspect.** By A. E. Baines. [Pp. xxii + 185.] (London: George Routledge & Sons, Ltd., 1921. Price 12*s*. 6*d*. net.)

The author opens the preface to this book with a homily addressed to reviewers asking them "to remember that a great humanitarian question is involved" and that "the fundamental truth" he has put forward "is of too great importance to mankind to be passed over, or to be, to all intents and purposes, shelved, by saying there is very little that is new in it."

As far as this reviewer can understand, the "fundamental truth" is that electrical stimuli are important factors in the life of organisms. A special case of this fundamental truth is dealt with in this volume, namely, the importance of electrical stimuli on germination of seeds. Now, in establishing any "fundamental truth" in biology it is not generally regarded as satisfactory to confine the experimental work to one or a few individuals, but, on account of the differences between individuals of the same species, to use large numbers of individuals. Again, everyone who has worked much with plants under experimental conditions knows how easy it is to ascribe results to one condition or a set of conditions when the decisive factor has been overlooked. The author, although he is certainly aware of these difficulties, in the opinion of the reviewer has not paid sufficient attention to either of them in his attempt to establish his "fundamental truth" with regard to germination.

The following statements will probably appeal to the botanist: "In his *Textbook of Botany*, Davis, writing of gymnosperms, cites the Selaginella, a common greenhouse plant, as an illustration of sexual reproduction." "In this the sporophyte bears male and female spores." "Botany should be a fascinating study to the young. It has been made a heart-breaking one, for the student has almost to master another language before he can become familiar with the structure of a single blossom." "It has been impressed upon me so frequently that the seed contains nutriment for the sustenance of the seedling that I have expected to find constant shrinkage of the seed substance as growth proceeded. Very many experiments have been made, but I have not seen any evidence of such shrinkage."

Perhaps sufficient comment on these statements is contained in another quotation from our author: "In the studies in Electro-physiology which follow I am going to assume that my readers are acquainted with all there is to be said upon the subject of botany."

W. S.

**British Basidiomycetæ.** A Handbook to the Larger Fungi. By Carleton Rea, B.C.L., M.A. [Pp. xii + 799.] (Cambridge: at the University Press, 1922. Price 30*s*. net.)

The need for a handbook to the taxonomics of the Basidiomycetous Fungi of Britain had become acute, not merely through the lapse of time since the publication of Smith's Synopsis in 1908, but particularly owing to the rapid advances in Mycology during recent years which have necessitated a revision of the basis of classification.

The arrangement here adopted is that put forward by Patouillard in 1900 in place of the system of Fries upon which previous Floras, even that of Smith, were based.

It is indicative of the growing interest in the subject that, whereas the "Fungus Flora" of Massee published in 1892 enumerated 1,980 species of Basidiomycetæ, the present work describes no less than 2,546. Of this total the Homobasidiæ (Gasteromycetales, Agaricales, Aphyllophorales, and Exobasidiales) embrace 2,477, the remaining 69 species of the Heterobasidiæ being chiefly members of the saprophytic families. Three groups of the parasitic Heterobasidiæ, viz. the Pucciniineæ, Coleosporiineæ, and Ustilagineæ, are not dealt with in this volume.

For each species a fairly full description is given of the macroscopic characters, of which the more important are indicated by the use of italics. Microscopic details, respecting the spore dimensions and the nature of the cystidia, are furnished for most species, whilst a very useful addition is that of references to where figures of each species can be found.

It adds considerably to the value of the descriptions that no small portion of these twenty-five hundred species have been seen by the author in the living state. Notes are also added as to the habitat and frequency, the period of development of the fruit body, and the significance of the Latin names.

Having regard to the adoption of an unfamiliar classification, the author has thoughtfully provided a key, occupying nineteen pages, to the genera and larger aggregates.

The thanks of botanists generally and mycologists in particular are due to the author for this excellent handbook, which represents the fruition of thirty years of labour. The format maintains the high standard we are accustomed to look for from the Cambridge Press, and we owe it to the subsidy provided by members of the British Mycological Society that the price renders this book one of the cheapest scientific works that has appeared in recent years.

E. J. S.

## ZOOLOGY

**British Mammals.** Written and illustrated by A. THORBURN, F.Z.S. [Vol. I, pp. 84; Vol. II, pp. 108; 50 plates in colour and pen-and-ink sketches in the text.] (London: Longmans, Green & Co. Price £10 10s.)

WE have at length had the pleasure of receiving the second volume of Mr. Thorburn's *British Mammals*, making it possible to review the work as a whole, and to give fuller attention to Vol. I than was considered advisable in the short preliminary notice that has already appeared (Vol. XVI, p. 490).

In size, appearance, and general arrangement these volumes match Mr. Thorburn's two previous works in the same series, "British Birds" and "A Naturalist's Sketch-book," and they are as beautifully produced. There is one noteworthy difference—the descriptive text accompanying the plates is considerably fuller. The author contributes but little original material, the notes being chiefly citations of other writers. They contain a wealth of information, and are admirably selected. For most of the species dealt with enough descriptive and anatomical details are included to make the letterpress an invaluable supplement to the plates for purposes of identification. The notes further include observations on life-habits, distribution, past and present, and, in the case of the rarer animals, the recorded occurrences that entitle them to a place on the British list. In this connection it may be noted that the inclusion of the Walrus in Vol. I has led to the writing of a special appendix to Vol. II. Here the author states that "As exception has been taken to the inclusion of this species (the Walrus) as a British mammal, it may be interesting to note that Mr. Henry Jamieson, Keeper of the Skerries Lighthouse, Shetland, reports the occurrence of a Walrus which haunted the neighbourhood of the islands from July till October 1920, as recorded in *The Scottish Naturalist* (Nos. 107–108, 1920)." He adds that this keeper claims two previous occurrences of this mammal off the islands during the last forty years.

The work concludes with brief notes on "Mammals extinct in the British Islands within Historic Times." The five following species are enumerated: Wolf, Brown Bear, Beaver, Reindeer, and Wild Boar. The Elk certainly, and the Lynx probably, should have been included.

Each volume is provided with a table of contents, but these, as also the preface, are printed on un-numbered pages. A useful index is provided. For some reason the pagination of the two volumes is discontinuous, but the plates are consecutively numbered from one to fifty, there being twenty-five in each part. The classification followed is that adopted by Mr. Millais in his *A History of British Mammals.*

As the author points out in the preface, the fact that British mammals are comparatively few (seventy species) has enabled him to be considerably freer with the allocation of space on the plates than was the case with his birds. This has made it possible to devote a single plate, and in some cases even two, to one species. Thus it is that the Mountain Hare and the Stoat are illustrated both in their winter and summer pelages on separate sheets. While these pictures possibly make us wish that Mr. Thorburn could have treated all his beasts in similar fashion, his grouping of several forms on a single plate is often so charmingly done that we admire these almost as much. Plates 9 (Shrews) and 26 (Harvest and Wood Mice) are good examples.

If there is any criticism to be made of the artist's beautiful work it is that some of his mammals lack character. The Wild Cat (Plate 10), though snarling and evidently disgruntled, is by no means a convincing cat. It lacks character. It is not really "catty." Nor is the Fox (Plate 11), in spite of his flamboyant brush, characteristically "foxy." The same sort of remark would be applicable to several others.

The majority, however, represent Mr. Thorburn at his best. It is difficult to conceive of anything more delightful than the Doormouse (Frontispiece, Vol. II) or the Stoat in winter pelage (Plate 22) or the Common Rabbit (Plate 36). Others that are particularly striking and pleasing are the Chartley and Chillingham Bull's-heads (Plate 41), the Stoat in summer pelage (Plate 21), and the Mountain Hares (Plates 34 and 35).

The pen-and-ink sketches, as previously remarked, do not compare with Mr. Thorburn's incomparable brush work. Very few, incidentally, are included in the second volume.

The publishers as well as the author deserve congratulation for successfully completing this beautiful work, which will be much valued by mammal students and lovers of art.

W. R.

**The Mechanism of Life in Relation to Modern Physical Theory.** By JAMES JOHNSTONE, D.Sc., Professor of Oceanography in the University of Liverpool. [Pp. xii + 248.] (London: Edward Arnold & Co., 1921. Price 15*s*. net.)

IF this book were expurgated and thereby reduced to about half its present size, it might form a useful introduction for those who, without being experts, are interested in the study of biological energetics from the standpoint of modern science. The physiological diagrams are nicely drawn, and there are many instructive illustrations of energy transformations in physics and chemistry.

As it stands, however, the work is a hodge-podge of a variety of undigested generalisations on Physical Science, Psychology, Philosophy, Relativity, non-Euclidean Geometry, etc., and on many points the author is misled and misleading. It seems a pity that he should thus throw discredit on the many sound statements contained in his book by a habit which Bacon described as *mater errorum et scientiarum omnium calamitas.*

Nevertheless, the capacity for generalising while keeping in close contact with particulars is one of the marks of genius (*e.g.* Newton, Darwin, and *perhaps* Einstein). A great scientific or philosophic generalisation is an instrument for production or ideal co-ordination. Dr. Johnstone appears to have a capacity for appreciating generalities, has a considerable knowledge of exact scientific data, and might produce an instrument of value, if he follows the advice of Goethe, to confine himself and not to try flying in several directions simultaneously.

R. A. P. Rodgers.

**Hormones and Heredity.** A Discussion of the Evolution of Adaptations and the Evolution of Species. By J. T. Cunningham, M.A., F.Z.S. [Pp. xx + 246, with 3 plates.] (London: Constable & Co. Price 24*s.*)

Prof. J. T. Cunningham is always interesting and stimulating even when we cannot agree with him. In this volume the author has wisely taken the precaution of publishing his original views on the supposed part taken by the internal secretions in heredity. It is a pity that that author's views should have been hidden away for so long, as he says himself, in one paper in a German periodical, and a chapter in an elementary textbook.

In the first part of this book Mr. Cunningham goes over the historical ground, and in later chapters he develops his theory so far as it concerns somatic sex-characters and certain non-sexual characters.

We think that the author hangs too much on his "hormone peg": we like the peg very much, but it will only bear a certain amount, and when he asks us to believe that the horns of animals arose by the irritation produced by generations of buttings, it seems difficult to credit that internal secretions alone can have been concerned.

With regard to his valuable discussion on Mammalian Sexual Characters, he states that "Marshall himself examined sections of the corpus luteum of Ornithorhynchus and saw much hypertrophied and apparently fully developed luteal cells, but no trace of any ingrowth from the wall of the follicle." Marshall is wrong here, for there is ingrowth in the platypus corpus luteum.

The author enters into some of the most difficult questions in the evolutionary theory: everywhere his work is interesting and worth reading. He tells us of many experiments, hitherto unpublished, which he has made. We trust that he will carry the unsuccessful ones to fruition.

We have no hesitation in saying that the author's book should be read by all who are interested in heredity and sex.

J. Bronté Gatenby.

**Heredity in the Light of Recent Research.** By the late L. Doncaster, Sc.D., F.R.S. Third Edition, revised. [Pp. vii + 161.] (Cambridge University Press. Price 4*s.*)

This useful little book by the late Prof. Doncaster will again be welcomed, because it has been revised especially in the light of the many recent researches on Mendelism, Heredity in Man, Sex, and especially in view of Prof. Morgan's important contributions, for which a special Appendix has been introduced. This book is written in such a way as to be useful for both the student and the intelligent layman.

J. Bronté Gatenby.

**The Evolution of Continuity in the Natural World.** By DAVID RUSSELL, M.D., Director of the British Hospital, and Doctor to the British Legation, Lisbon. [Pp. vi + 278, with 3 illustrations.] (London: George Allen & Unwin. Price 16*s*. net.)

WE hesitate to say whether the doctor has been wise to venture from the hospital portals into the treacherous sands of biological philosophy. To the ordinary zoologist this book will seem strange, and, to be candid, difficult to understand. The author begins his book with the aid of two glass beads on a tray at a little distance from each other. By means of these glass beads he explains the plot: the beads on the tray are in a state of Discontinuity—but by bringing the beads together this Discontinuity is changed to Continuity. "The evolution of Living Continuity, whose attempted demonstration is the main object of this book, is only one aspect of an evolution of Continuity," etc. "Matter owes its existence to the institution of Continuity." Again: "Man can produce endless systems of Continuity higher than the molecular: for example, he can make a large number of bricks; can unite them together to form a house; can make a number of similar houses joined together in a row," etc.

This is not a description of a colliery village, or of Pimlico—as one might think at first. At any rate, the author dogmatises on every question from the peculiar behaviour of the two glass beads, to the Evolution of Matter, and again to the Origin of Species and the Cause of Cancer.

Seriously, we cannot deal with this book much further. The author's chapter on Karyokinesis, for example, is pure rubbish from beginning to end: he is unacquainted with the literature of the subject. The other chapters are equally useless, and the book simply bristles with statements which would only be made by one whose knowledge of modern biology is extremely curtailed. We are sorry thus to speak of the work of the author, but we are unable to understand why the book came to be published.

J. BRONTÉ GATENBY.

**A Textbook of Zoology.** By the late T. JEFFERY PARKER, D.Sc., F.R.S., and WILLIAM A. HASWELL, M.A., D.Sc., F.R.S. [Vol. I, pp. xl + 816, with 713 figures; Vol. II, pp. xx + 714, with 503 figures.] (London: Macmillan & Co. Price 50*s*. net.)

THIS is the third edition of this splendid work. It has been revised by Prof. Haswell, with much help from Prof. W. N. Parker, who had already been identified with the two earlier editions.

The Nemathelminthes, Molluscoida, and the Annulata have been especially revised. There can be no doubt that in those Universities where the Final Examination is constituted by two subjects such as Zoology and Botany, these two volumes by Parker and Haswell make a very convenient textbook. Eked out with special professorial lectures and good practical classes, Parker and Haswell's book would be a most suitable basis for the student.

The articles at the end of the second volume are very good. The work needs no recommendation from us.

J. BRONTÉ GATENBY.

**Birds One should know, Beneficial and Mischievous.** By the REV. CANON THEODORE WOOD. [Pp. xi + 132, with numerous coloured and uncoloured illustrations, by Roland Green, F.Z.S.] (London: Gay & Hancock, 1921. Price 10*s*. 6*d*. net.)

THE main purpose of the brief text accompanying the illustrations of the 33 species with which the author deals is to indicate their value to the agriculturist and horticulturist. This is achieved in a pleasing and simple manner. It is a matter of regret that the author does not cite his authority for the many extraordinary statements that are to be found in the text. Possibly the most startling is that the cuckoo cannot call from the end of June till its next mating season since it "loses its voice" for that period. But many others, such as the assertion that the brown colour on the head of the Black-headed Gull "fades away" in the autumn, leaving it entirely white, are almost as surprising.

Mr. Green's illustrations are delightful, particularly the monochrome plates.

The general get-up of the book is most pleasing. The remarkable price of 10s. 6d. in these prohibitive days should ensure it a sale, and it will no doubt do some good in the cause of bird protection, but its limited scope and the fact that it is bristling with inaccuracies will prove a handicap.

W. R.

**The Cuckoo's Secret.** By EDGAR CHANCE, M.B.O.U. [Pp. x + 237, with frontispiece, 15 photographs, and 2 maps.] (London: Sidgwick & Jackson, 1922. Price 7s. 6d.)

THE major portion of the book consists of a record of facts, the concluding chapters are theoretical. The records cover four seasons of careful systematic work, and are of the most extraordinary interest. Mr. Chance's film, which enjoys the same title as his book, is now well known. It is one of the products of his labours, and selected prints from it are included in the volume under notice, as well as pictures taken with an ordinary camera. The points on which the author lays chief emphasis are the following: A cuckoo may lay as many as twenty-one eggs in a season, these being produced generally on every second day, though a normal set, *i.e.* one laid without human interference, is probably much smaller; an individual cuckoo is not promiscuous in its choice of fosterers, but prefers a given species (in this case the meadow pipit); the bird actually lays its egg in the nest and not outside it, later to transfer it thither by means of its beak or its throat; the hen cuckoo owns a territory in the same way as do the males of most other species. There are, in addition, many minor points of interest.

The limited space at our disposal prevents us from discussing the author's theories expounded in the closing chapters. One cannot help thinking that these might have differed considerably if looked at from some other standpoint. Some, at least, fail to carry conviction. There seems to be no support in the recorded observations for the theory that the cuckoo deliberately victimises the same individual foster birds season after season. It is hard to believe that the taking of the cuckoo's eggs as laid is a stimulus to the bird to continue laying. The explanation offered for the fact that reddish eggs of the cuckoo have been found in robins' nests, and bluish ones in the hedge sparrows', is ambiguous, and if read in the way evidently intended, highly improbable.

Stuart Baker in a recent paper (*Bull. Brit. Ornith. Club*, March 1922) has made some interesting criticisms of some of Mr. Chance's other contentions, their expressed views on some points being exactly opposed.

It is a pity that after the author has emphasised his objections to the all too frequent custom of generalising from limited observations he should himself fall into the trap. He states in chapter xvi that "I am quite sure, from having constantly kept a daily watch on cuckoos for the last four years, that the hen cuckoo does not utter the 'cuck-oo' note." The "daily watch on cuckoos" consisted chiefly in watching a particular hen cuckoo, actually not daily, but more generally every second day (laying day) for four seasons. It is true that observations were made also on others, but these appear to have been more casual, although these too were made mostly on laying days. The author has evidently not had his attention called to the note in *The Countryside* for 1914, by J. Whitaker, recording the case of a cuckoo shot in the act of "cuck-ooing" which, on dissection, proved to be a female.

No index is provided, which seems a serious defect in a book that will certainly be used a great deal for reference. Since the author states that he has hunted out most of the known cuckoo literature, a bibliography would have been welcomed by most readers. The appendix, giving the weights of cockoos' eggs, is of great interest and lends remarkable support to some of the author's observations. The work involved was done by Mr. P. F. Bunyard.

Whatever criticisms one may make, there is no doubt that Mr. Chance's work is a landmark in ornithological field methods of to-day. He has thoroughly aroused universal interest in his subject—a tribute well worthy of the untiring efforts that made it possible for him to arrange for the cinematograph to be on the right spot to film the laying of the cuckoo's egg and to expose to the world her secret.

W. R.

## ANTHROPOLOGY

**Prehistory.** By M. C. Burkitt, M.A., F.G.S. [Pp. xx + 438, with 47 plates.] (Cambridge University Press, 1921. Price 35*s.*)

Books of first-class merit dealing with prehistoric man appear in this country at the rate of about one a year, and this work by Mr. Burkitt is the latest addition to the series. It might appear that another volume on this much-discussed subject would prove superfluous, but in reality this is not so. The chief English books only partially duplicate one another. In the different books the stress is laid on different aspects of prehistory. James Geikie deals more attractively with the geology of the Pleistocene than does any other writer. Sollas gives the geology and also includes accounts of living savages. Osborn gives a popular and pleasant, though hastily compiled, description of the men of the Old Stone Age. Keith discusses the anatomical aspects of the subject with unparalleled thoroughness. And now we have Mr. Burkitt's beautifully produced work, of which the appropriate sub-title is " A Study of Early Cultures in Europe and the Mediterranean Basin." The author is concerned with the culture and industries of the peoples, rather than with the peoples themselves. It is essentially a book on prehistoric archæology, or rather, on palæolithic archæology (the later periods are treated only cursorily) ; and quite a secondary position is given to the geological and anatomical aspects of the subject. This is quite as it should be. There was a call for such a work with the stress on the archæology ; and Mr. Burkitt, who has a first-hand knowledge of many of the famous French and Spanish prehistoric caverns, has given us an excellent and very complete and detailed study of this side of the subject.

The book contains twenty-two chapters, of which all except four may be described as archæological, the descriptions of palæolithic art being naturally very full. Thus Chapter VI deals with " Lower Palæolithic Civilisations," Chapter VII with " Mousterian Civilisation," Chapter IX with " The Aurignacian Age," Chapter XI with " The Magdalenian Age," and Chapter XX with " Eastern Spanish Art." All these chapters have an amount of detail in them which English readers will not find elsewhere, and the text is illustrated by a magnificent series of plates, which are conveniently aggregated at the end of the volume. The author gives an outline of the geological and anatomical aspects of prehistory only sufficient to make his archæology comprehensible. There are two chapters on geology, in which the author wisely assumes that his readers are completely ignorant of this subject. In the main, the elementary exposition in Chapter II is good, but he forgets to explain the meaning of the word Pleistocene ; and, moreover, the term " Quaternary " is ordinarily used to connote both Pleistocene and Recent, not Pleistocene only. Mr. Burkitt is in good geological company in using the terms Tertiary and Quaternary, but they are nevertheless mischievous terms, and it is much better to use the single name Cainozoic for what is essentially a single geological era. The anatomy is given only one chapter. It is doubtless because the author does not see his subject from the anatomical side, that he does not sufficiently emphasise the great break in the middle of the so-called Palæolithic period. He says (p. 120) that the division between the Upper Palæolithic and the Lower Palæolithic "should be considered as great as that between the Upper Palæolithic and the Neolithic Ages." In point of fact, the division between Lower and Upper Palæolithic is much greater than any subsequent break, and it is only by the use of Elliot-Smith's term Neanthropic that this point can be brought out in classification. This might have been more emphasised.

The book has a preface by L'Abbé Breuil under whom Mr. Burkitt studied in France; and there is a long bibliography, containing references to a great number of the most important books and papers, but with the singular omission of one famous classic, namely, Lord Avebury's *Prehistoric Times*, of which a new and revised edition was published as recently as 1913. The plates include some representations of remarkable prehistoric engravings on rocks in the region of Lake Onega, in North Russia.

A. G. T.

## MEDICINE

**Arab Medicine and Surgery.** By M. W. Hilton-Simpson, B.Sc. (London: University Press, Humphrey Milford, 1922. Price 10*s*. 6*d*. net.)

Mr. Hilton-Simpson need have no qualms about his lack of medical knowledge, as he has been most successful in presenting not only the medical profession but the general reader with a most interesting book on an almost unknown subject. Since the earliest times the Arabs have practised the art of healing, and with the earlier proselytisers this knowledge penetrated to the very heart of Africa. Few are the primitive native races which have not their medicine man, who is, as a rule, the most powerful individual in the tribe. What the medicine man of the negroid races lacks in knowledge of herbs and their uses and in surgical skill he makes up with magic—the latter usually preponderating. The more enlightened the tribe the less magic enters into the medicine man's stock-in-trade.

It is not surprising that even among the Arab practitioners of such remote spots as the Aures Mountains, Mr. Hilton-Simpson found that magic still plays a great part in the treatment of the sick. Here the skin of the viper, the blood from the freshly-cut throat of the hoopoe, and the white portion of the dung of a species of lizard, all have their uses.

Among the pastoral tribes of Africa the fresh dung of cattle is very commonly smeared over ulcers and open wounds or used in the form of a poultice over inflamed areas. Common articles of food such as milk, oil, dates, and honey are used to render more palatable the herbs gathered from the hillsides. Cautery is usually more common among the more primitive races than among the Arabs generally. Among the Bantu tribes in particular it seems to be the favourite panacea for every variety of internal and external ill, while among certain tribes in Equatorial Africa the free use of this form of counter-irritation has been used for the purpose of adornment, particularly on the chest, abdomen, and back. The value of Mr. Hilton-Simpson's book is greatly enhanced by the identification of all the plants used by the Arab physicians. There appear to be few among them, however, which can be said to have any real medicinal value.

The author is to be congratulated on the very complete collection of surgical instruments he made, while the amount of information he extracted from the Arab practitioners themselves regarding their craft reflects the greatest credit on his methods in dealing with a race who are by nature suspicious and secretive.

The photographs illustrating the results of Arab surgery are excellent, as also are those showing the collection of surgical instruments. A short index completes this little book, which will make a valuable addition to a scientific library.

R. E. Drake-Brockman.

## ENGINEERING

**Modern Practice in Heat Engines.** By Telford Petrie, M.Sc., Assoc.M. Inst.C.E., A.M.I.Mech.E. [Pp. xi + 264, with 111 illustrations and 2 folding plates.] (London: Longmans, Green & Co., 1922. Price 15*s*. net.)

The idea of forming, as the author states, a companion volume to the late W. Inchley's *Theory of Heat Engines* is good, giving one an insight into the practical side of the work as well as into the theoretical. In the hands of the average student, the practical end of an engineering problem is too often neglected and this is of course assisted by the tendency of so many writers to confine themselves purely to the theoretical side. Again, the authors of the so-called practical books are too ready to state purely what is current practice, so that in many instances the resulting text is little better than a collection of makers' catalogues and a few "shop" notes.

It is, therefore, pleasing to find grouped in the first section three chapters co-ordinating descriptive matter, an account of experimental work in connection with the development of modern boilers and also their construction. A few notes in Chapter II giving some idea of the advantages and suitability for particular duties of the various types would have improved the section slightly.

The next section deals with the steam prime mover. In Chapter V the terms "efficiency" and "efficiency ratio" are not used with sufficient distinction. Again, with regard to the illustrations in this section, these do not convey to the inexperienced their full meaning. A photograph or two of the various turbine internals on the lines of figs. 51 and 52 of the previous section would have made these points clearer.

The late W. Inchley's text makes no mention of the "Wilson line" and its effect on turbine design, and so in a companion volume it is a little disappointing to find merely a bald reference to this matter without explanation. The chapter on the reciprocating engine is a great improvement on the remainder of the steam section, discussing the reasons for and effects of various modifications in design.

The last section, on the internal combustion engine, commences with a useful collection of expressions for the internal energy of the working substance. On this follows a good description of the different types of engine, while, in the last chapter, the author shows the use of Walker's energy chart in an actual design.

It is apparent that the whole of the work has been carried out with considerable care, although it is noted that in the case of the larger Ljungström turbine the exhaust blading is described as of the Parsons type, while the diagram shows an impulse blade. The author is to be congratulated on having produced a useful companion volume, and it is to be hoped that it will enjoy the popularity of its fellow.

**Steam Turbines.** By W. J. Goudie, D.Sc., M.I.Mech.E., Assoc.M.Inst.C.E. [Pp. xvi + 804, with 329 illustrations and numerous examples.] (London: Longmans, Green & Co., 1922. Price 30*s*. net.)

The preface to the first edition of this book states that it was written primarily for engineering students, but that it was hoped that the methods of calculation outlined would be useful to engineers. It is evident that the author has had this well in mind in preparing his second edition. For the student and also the engineer who wishes to keep up-to-date in the development of machinery, it is essential to be able to refer to descriptions of various plants. For the student it is necessary, not only that he may understand the general methods of operation, but to give him also an idea of the problems to which to apply his theory, for too many texts are given us which deal with raw theory alone, not co-ordinating with it the practical part of the problem.

The first part of the text deals very fully with the various types and their methods of operation and is amply illustrated. In Chapter VI are discussed the Callendar formulæ for steam, including their uses in the case of supersaturation, several arithmetical examples being given to make matters clear.

The important methods of "Nomographic Calculation" as applied to the total heat per pound of steam are carefully explained, although the use of a series of large diagrams in the design office is often not as convenient as it might appear.

The matter of nozzles and blading has been dealt with in a complete and masterly way from both practical and theoretical points of view. The question of stresses in modern turbine blading, which have increased considerably during the last decade, has been discussed freely.

A marked reduction in the amount of arithmetical work has been effected in the solution of the equations for disk stresses by the use of certain charts. On this follows the question of critical speeds, and in this connection an example on the "three-bearing" problem is worked out fully.

In a chapter on Mechanical Reduction Gears are set forth clearly the pros and cons of various designs of gears, together with the stresses and strains involved. It may be a little questionable as to whether the matter of gearing finds a proper place in a text on the turbine, in spite of their close relationship, but the excellence of the treatment more than justifies its inclusion.

Under Steam Consumption the use of correction curves for varying steam conditions is given, also the correction for changes of vacuum for partial loads, a matter generally neglected.

Many turbine designers are at present directing their attention to the matter of "feed heating," thus introducing the regenerative principle into the steam cycle. The improvement of efficiency due to this is explained and fully worked out in an actual example.

A design is given for each of the standard types of machine, the procedure being set out clearly, while in the final chapter are explained the usual methods of governing, and this, as throughout the text, is copiously illustrated.

The new edition is certainly the standard text, and Prof. Goudie is to be heartily congratulated on his production.

## MISCELLANEOUS

**The Petroleum and Allied Industries.** By James Kewley, M.A., F.I.C. [Pp. xii + 302, with 41 figures in the text.] (London: Baillière, Tindall & Cox, 1922. Price 12*s*. 6*d*. net.)

This volume is one of a series of fifteen published works dealing with the more important phases of industrial chemistry. In scope, the work is certainly more ambitious than most of its companion volumes, since the task of condensing the many and varied ramifications of the petroleum industry into the compass of a book of this size is indeed formidable. We have only to think of the latest edition of Redwood to appreciate this point. There are, in fact, exceedingly few men who would contemplate the task with equanimity —still fewer would achieve satisfactory results. Although there is admittedly much that disappoints in the work, Mr. Kewley has undoubtedly been successful (if we do not interpret the title too literally), because he passes rapidly over those aspects of the industry with which he perhaps feels himself less qualified to deal, and concentrates on those branches of the subject, the study of which he has made so essentially his own. As a masterly summary of modern refinery principles and practice, we have yet to see a better book: as a comprehensive survey of the *whole* industry, it is somewhat disappointing.

The book is divided into nine parts. Part I is introductory and includes sections on the history, chemistry, geology, theories of origin of petroleum (the author is rightly non-committal in this latter connection), together with a glossary which suffers from being unduly brief. Part II is devoted to natural gas, Part III to the occurrence, production (drilling methods), storage, and transport of petroleum. Part IV embodies the essentials of the oil-shale industry; its descriptive sections are weak, but the chemical aspects, more especially the laboratory examination and retorting of oil-shales, are lucidly discussed. We are glad to note the author's advocation of the "drainpipe" retort rather than the "pot" still for laboratory shale-testing: the latter, favoured in some laboratories, invites the serious disadvantage of ununiform heating, with consequent internal "cracking" and inaccurate evaluation. Part V describes the solid bitumens, Part VI being devoted to ozokerite (it is curiously spelt without the final "e" in several places) and montan wax. Parts VII and VIII, by far the best in the book, discuss the working-up of crude oils and the characters and applications of their products. A short part (IX) on oil-testing concludes the text.

With the above reservations, we have no hesitation in recommending this book to all those interested in or directly connected with a great industry.

H. B. Milner.

**Science in the Service of Man: Electricity.** By Sydney G. Starling, B.Sc., F.Inst.P. [Pp. viii + 245, with 127 illustrations.] (London: Longmans, Green & Co., 1922. Price 10*s*. 6*d*. net.)

The object of this book is to give a non-mathematical account that will appeal to the general reader of the present stage of electrical knowledge. The author, starting from the simplest electric and magnetic phenomena, deals in turn with their many industrial applications, and the book, though it does not claim to describe the latest forms of particular instruments, is yet full enough of detailed information to answer the questions which most interest the lay reader. A specially popular chapter will be that dealing with electromagnetic theory and wireless telegraphy.

The last two chapters deal with X-rays, the conduction of electricity through gases and radioactivity, and it seems a pity that more space could not have been devoted to these modern developments, whose romantic story cannot fail to appeal to the popular imagination. The disproportion is, however, so often in the opposite direction that the author's arrangement does a service in emphasising that the discovery of the electron was not the beginning of wisdom, or of the application of electrical resources to the service of the community.

G. A. S.

**The Teaching of General Science.** By W. L. Eikenberry. [Pp. xiii + 169.] (Chicago: The University of Chicago Press.)

Apart from the chapters that deal with the practice of science teaching in the American schools, this book is a valuable contribution to the study of the pedagogics of science teaching and might be read with profit by all teachers of science. The earlier chapters, dealing with the methods of teaching science in the American schools, the character and average content of their textbooks, and the general organisation of the subject in the schools, is of less interest to English teachers than to Americans. Consequently other than American teachers will find their chief interest in Chapters IV to VI, which are mainly concerned with the purely pedagogic aspect of the subject. It is interesting to note that lack of breadth of vision is not a fault confined to English school teachers of science.

W. C. B.

**A New System of Scientific Procedure.** By G. Spiller. [Pp. ix + 441, 8vo.] (London: Watts & Co., 1921.)

Mr. Spiller is known as the author of various books on psychology, education and sociology. In the volume under review he attacks the problem of methodology. He has evidently read extensively the literature of science and scientific method—perhaps too extensively for complete assimilation—and the results presented in the new work are certainly interesting and likely to be profitable to those who will devote to it the necessary time and thought. The literature on methodology is so scanty that a serious contribution like Mr. Spiller's present volume is sure to be welcomed even by those who cannot see eye to eye with him.

For the most part writers on scientific method have hitherto been logicians or philosophers whose interests and aims were essentially theoretical. They were usually content to schematise the more usual scientific methods and to point out the philosophical or logical assumptions underlying the procedure of science. Mr. Spiller does not entirely ignore the theoretical side of his subject—indeed, about a third of the volume is devoted to it—but he is chiefly concerned with the practical value of his exposition. Mr. Spiller is rather contemptuous of logic, although his contempt is not the outcome of familiarity, to judge by the curious way in which he repeatedly confounds "deduction" with the "deductive method." His aim is essentially practical. Like Bacon, he inclines to the belief that any normal person might become a man of science by studying and following his precepts; and, like Huxley, he seems to hold that most, if not all, human ills might be remedied by the aid of science and scientific methods. The bulk of the volume is taken up with an exposition and illustration of thirty-five "conclusions" or articles in which Mr. Spiller sums up his analysis of the procedure of science at its best. In the course of his exposition of these very comprehensive thirty-five articles, Mr. Spiller has the courage to refer even to the "financial and other support" of men of science as an important element in the "personal equation." Mr. Spiller does not seem to have overlooked any detail. If anything there is perhaps too much detail in this painstaking book. The danger is that it may appear to be a piece of pedantry to those who will not take it seriously, while those who do take the book seriously may be unduly alarmed by these overwhelming demands that seem to be made from those who propose to follow the steep path of science. To some extent, however, the inevitable hardness of this serious book is softened by the numerous happy illustrations, drawn from science and social and political life, which the learned author has included in it.

A. Wolf.

**Early Science in Oxford. Part II, Mathematics.** By R. T. Gunther. [Pp. 101.] (Oxford: at the University Press, 1922. Price 10*s.* 6*d.* net.)

In the *Companion to the Almanac* for 1837, Augustus De Morgan gave a summary account of English mathematicians before 1600, and pointed out that the treatment of early mathematics in England in the histories of mathematics, *e.g.* Montucla, was hopelessly inadequate. Very little has even yet been done to fill the gap, and it was therefore with pleasurable anticipations that we opened this book. But the title is misleading; the main item is an annotated list of mathematical instruments which were exhibited in the Bodleian Library in the summer of 1919. To this are appended useful notes on mathematical instrument makers. The introductory "Notes on Early Mathematicians" raised our hopes, but on examination were found to contain little information that is new. One is, perhaps, rather tired of reading the rhyme about the introduction of Euclid into England in the time of Athelstan, and his mention in a book on Oxford is bound to suggest what Maitland called "the oldest of all inter-university contests—a lying match." In connection with Euclid, isn't it about time that somebody really read the versions of Adelard of Bath, with their curious abbreviated proofs, and determined the relation of his translation to those of Gerard of Cremona and Campanus? The literature of the subject is already large, but it is confusing and inconclusive.

Mr. Gunther doesn't even mention the mathematics of Roger Bacon, one of Mr. Wells's twelve greatest men, or of Grosseteste, while Sacrobosco and the Merton School of the fourteenth century are dismissed in a few lines, the latter with the pious regret that their MSS. have never been printed. Robert Recorde, however, is dealt with in more detail, and interesting facsimiles and quotations from his works are given. One question and answer from the *Grounde of Artes* is worth requoting:

"*Scholar.* Syr, what is the chiefe use of Multiplication.

"*Mayster.* The use of it is greater than you can yet understand."

The St. Andrew's cross used in the process of casting out the nines and in the multiplication of integers between five and ten should not, however, be described as a sign of multiplication (see Cajori in the *Mathematical Gazette*, October 1922, pp. 126–43). Also there seems to be some doubt as to the date of the first edition of the *Grounde of Artes*; the D.N.B. gives editions in 1540, 1542, etc.; Cajori gives 1543 (?), and Mr. Gunther 1542.

The author points out with justice that the only two Cambridge mathematicians of any note in the first half of the sixteenth century both migrated from Oxford, but it is surely going too far to describe Cambridge as the home of "what has been the most brilliantly successful mathematical school in the world."

Emphasis is naturally laid in this account on the invention of mathematical instruments, the quadrant of Gunter, the slide-rule of Oughtred, and the beam compasses of Francis Potter, so that the pure mathematician of to-day reads with appreciation the tale, quoted from Aubrey's *Lives*, of how Sir Henry Savile, being about to appoint his first Professor of Geometry in Oxford, sent for Gunter, who came "and brought with him his sector and quadrant, and fell to resolving of triangles and doeing a great many fine things. Said the grave knight, *Doe you call this reading of Geometrie? This is showing of tricks, man!* and so dismisst him with scorne, and sent for Henry Briggs from Cambridge."

The list of instruments itself is full of interesting information, and the plates of instruments are excellent, but one may not, perhaps, be inclined to accept Roger Bacon's dictum: "Without mathematical instruments no science can be mastered," with which the introductory notes terminate.

But when will the History of Mathematics in England be written?

F. P. W.

## BOOKS RECEIVED

*(Publishers are requested to notify prices)*

Bell's Mathematical Tables, together with a Collection of Mathematical Formulæ, Definitions, and Theorems. By L. Silberstein, Ph.D. London: G. Bell & Sons, 1922. (Pp. xi + 250.) Price 16*s*. net.

Likely to be useful to calculators. The first part consists of five-figured tables of logarithms and of trigonometrical functions, with some other matter. The second part "contains a collection of mathematical formulæ, definitions, and theorems, together with tables of the more important special functions." The author thinks that the need for such a book has long been evident. Differential and integral equations are not dealt with.

A Treatise on the Integral Calculus, with Applications, Examples, and Problems. By Joseph Edwards, M.A., Principal of Queen's College, London. Vol. II. London: Macmillan & Co., St. Martin's Street, 1922. (Pp. xv + 980.) Price 50*s*. net.

Differential Equations. By H. B. Phillips, Ph.D., Associate Professor of Mathematics in the Massachusetts Institute of Technology. New York: John Wiley & Sons; London: Chapman & Hall, 1922. (Pp. vi + 78.) Price 6*s*. 6*d*. net.

Cours de Physique mathématique de la Faculté des Sciences. Par J. Boussinesq, Compléments au Tome III Conciliation du Véritable Déterminisme mécanique avec l'Existence de la Vie et de la Liberté morale. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. xlviii + 217.) Price 30 frs.

Théorie des Nombres. Par M. Kraïtchik. Avec une Préface de M. d'Ocagne. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. ix + 229.) Price 25 frs. net.

Méthodes et Problèmes de Théorie des Fonctions. Par Emile Borel. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. ix + 148.) Price 12 frs. net.

Fundamentals of Practical Mathematics. By George Wentworth, David Eugene Smith, and Herbert Druery Harper. London and New York: Ginn & Co. (Pp. vi + 202.) Price 5*s*. 6*d*. net.

Machine-shop Mathematics. By George Wentworth, David Eugene Smith, and Herbert Druery Harper. London and New York: Ginn & Co. (Pp. v + 162.) Price 5*s*. 6*d*. net.

Les Applications élémentaires des Fonctions hyperboliques à la Science de l'Ingénieur électricien. Par A. E. Kennelly. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1922. (Pp. viii + 140.) Price 15 frs. net.

General Astronomy. By H. Spencer Jones, M.A., D.Sc., Chief Assistant at the Royal Observatory, Greenwich. London: Edward Arnold & Co., 1922. (Pp. viii + 39, with 24 illustrations.) Price 21*s*. net.

Molecular Diffraction of Light. By C. V. Raman, M.A., Hon. D.Sc., Palit Professor of Physics in the Calcutta University. Published by the University of Calcutta, 1922. (Pp. x + 103.)

Radio Receiving for Beginners. By Rhey T. Snodgrass and Victor F. Camp, A.I.R.E. London: Macmillan & Co., St. Martin's Street, 1922. (Pp. 99.) Price 3*s*. 6*d*. net.

Heat. By W. J. R. Calvert, M.A., Assistant Master at Harrow School. London: Edward Arnold & Co. (Pp. viii + 336, with 138 diagrams.) Price 6*s*. net.

The Origin of Spectra. By Paul D. Foote, Physicist, U.S. Bureau of Standards, and F. L. Mohler, Physicist, Bureau of Standards. American Chemical Society Monograph Series. New York: The Chemical Catalog Company, 19 East 24th Street, 1922. (Pp. 250.) Price $4.50.

Radio for Everybody. By Austin C. Lescarboura, Managing Editor, *Scientific American*, edited by R. L. Smith-Rose, M.Sc., D.I.L., of the National Physical Laboratory. London: Methuen & Co., 36 Essex Street, W.C. (Pp. xii + 308, with 163 illustrations.) Price 7*s*. 6*d*. net.

A Theory of Natural Philosophy. Put forward and explained by Roger Joseph Boscovitch, S.J. Latin-English Edition from the Text of the First Venetian Edition. Published under the Personal Superintendence of the Author in 1763; with a Short Life of Boscovitch. Chicago and London: Open Court Publishing Company, 1922. (Pp. xix + 463.) Price 63*s*. net.

The Practical Applications of X-Rays. By G. W. C. Kaye, O.B.E., M.A., D.Sc., A.R.C.Sc., F.Inst.P., Head of the Radiology Department, the National Physical Laboratory, Past President of the Röntgen Society. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1922. (Pp. viii + 135, with 96 figures.) Price 10*s*. 6*d*. net.

Atomic Form. With Special Reference to the Configuration of the Carbon Atom. By Edward E. Price. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. viii + 140.) Price 5*s*. net.

The Principle of Relativity with Application to Physical Science. By A. N. Whitehead, Sc.D., F.R.S., Hon. D.Sc., Hon. LL.D., Fellow of Trinity College, Cambridge, and Professor of Applied Mathematics in the Imperial College of Science and Technology. Cambridge: at the University Press, 1922. (Pp. xii + 190.) Price 10*s*. 6*d*. net.

A Textbook of Practical Physics. By W. Watson, C.M.G., A.R.C.S., D.Sc., F.R.S. Third edition, revised by H. Moss, M.Sc., A.R.C.S., D.I.C. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. xvii + 635.) Price 12*s*. 6*d*. net.

Advanced Laboratory Practice in Electricity and Magnetism. By Earle Melvin Terry, Ph.D., Associate Professor of Physics, University of Wisconsin. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. xi + 261.) Price 15*s*. net.

The Meaning of Relativity. Four Lectures delivered at Princeton University, May 1921. By Albert Einstein. Translated by Edwin Plompton Adams, Professor of Physics, Princeton University. London: Methuen & Co., 36 Essex Street, W.C. (Pp. 123, with 4 diagrams.) Price 5*s*. net.

Recent Rubber Progress in Rubber Chemistry and Technology. By Philip Schidrowitz, Ph.D., F.C.S. London: Benn Brothers, Ltd., 8 Bouverie Street, E.C.4, 1922. (Pp. 64.) Price 3*s*. 6*d*. net.

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An Introduction to the Chemistry of Plant Products. Vol. II. Metabolic Processes. By Paul Haas, D.Sc., Ph.D., Reader in Plant Chemistry in the University of London, University College, and T. G. Hill, A.R.C.S., F.L.S., Reader in Vegetable Physiology in the University of London, University College. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. viii + 140.) Price 7*s*. 6*d*. net.

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Inorganic Chemistry. A Textbook for Schools. By E. J. Holmyard, B.A. London: Edward Arnold & Co., 1922. (Pp. xi + 560, with 10 plates.) Price 6*s*. 6*d*. net.

The Volatile Oils. By E. Gildemeister and Fr. Hoffmann. Second Edition, by E. Gildemeister. Written under the Auspices of the Firm Schimmel & Co., Miltitz, near Leipzig. Authorised Translation, by Edward Kremers. Vol. III. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. xx + 777, with 5 maps, 1 table, and 51 illustrations.) Price 32*s*. net.

La Molécule. Equilibres et Réactions chimique. Par Dr. Achalme, Directeur de Laboratoires, l'Ecole des Hautes Etudes. Les Edifices Physico-Chimiques. Tome II, avec des dessins à la Plume de M. Raoul Leclerc. Paris: Payot et Cie, 106 Boulevard Saint-Germain, 1922. (Pp. 239.) Price 15 frs.

A Laboratory Handbook of Bio-chemistry. By P. C. Raiment, B.A., M.R.C.S., L.R.C.P., and G. L. Perkett, B.A. London: Edward Arnold & Co., 1922. (Pp. 102.) Price 5*s*. net.

The Theory of Allotropy. By A. Smits, Ph.D., Professor of Chemistry in the University of Amsterdam. Translated from the German with the Author's sanction by J. Smeath Thomas, D.Sc., Senior Lecturer of Chemistry in the University of Liverpool. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. xiii + 397, with 239 figures.) Price 21*s*. net.

Graphical and Tabular Methods in Crystallography as the Foundation of a New System of Practice. With a Multiple Tangent Table and a 5-figure Table of Natural Cotangents. By T. V. Barker, University Lecturer in Chemical Crystallography and Fellow of Brasenose College, Oxford. London: Thomas Murby & Co., 1 Fleet Lane, E.C.4. (Pp. xiv + 152.) Price 14*s*. net.

An Introduction to Sedimentary Petrography, with Special Reference to Loose Detrital Deposits and their Correlation by Petrographic Methods. By Henry B. Milner, M.A., D.I.C., F.G.S., A.M.I.P.T., Lecturer in Petroleum Technology, Imperial College of Science and Technology, London. London: Thomas Murby & Co., 1 Fleet Lane, E.C.4. (Pp. 125, with 32 figures.) Price 8*s*. 6*d*. net.

Handbook to Hull and the East Riding of Yorkshire. Prepared for the Members of the British Association for the Advancement of Science on the Occasion of their Visit to Hull in September 1922. Edited by T. Sheppard, M.Sc., F.G.S., Hon. Local Secretary. London and Hull: A. Brown & Sons, 1922. (Pp. viii + 552, with illustrations.)

Laboratory Manual of Fruit and Vegetable Products. By W. V. Cruess, B.S., and A. W. Christie, M.S. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. vii + 109, with 12 figures.) Price 7*s*. 6*d*. net.

Researches on Cellulose IV. 1910–1921. By Charles F. Cross and Charles Coree. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. x + 253, with 4 plates and 12 diagrams.) Price 15*s*. net.

Guide to the University Botanic Garden, Cambridge. By Humphrey Gilbert Carter, Director of the Garden. Cambridge: at the University Press, 1922. (Pp. xv + 117, with 23 plates.) Price 3*s*. 6*d*. net.

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Smell, Taste, and Allied Senses in the Vertebrates. By G. H. Parker, Sc.D., Professor of Zoology, Harvard University. Philadelphia and London: J. B. Lippincott Co. (Pp. 192.) Price 10*s*. 6*d*. net.

Essentials of Zoology. For Students of Medicine and First Year Students of Science. By Alexander Meek, Professor of Zoology, University of Durham. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4. (Pp. xii + 325, with 145 illustrations.) Price 10*s*. 6*d*. net.

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The Wonderland of the Eastern Congo. The Region of the Snow-crowned Volcanoes, the Pygmies, the Giant Gorilla, and the Okapi. By T. Alexander Barns, F.R.C.S., F.Z.S., F.E.S., with an Introduction by Sir H. H. Johnston, G.C.M.G., K.C.B., D.Sc. London: G. P. Putnam's Sons, 24 Bedford Street, W.C.2. (Pp. xxxv + 288, with 108 illustrations.) Price 31*s*. 6*d*. net.

La Memoria Biologica Saggi di una Nuova Concezione Filosofica della Vita. By Eugenio Rignano. Bologna: Nicola Zanichelli. (Pp. 249.) Price 17.50 l.

Mosquito Eradication. By W. E. Hardenburg, Sanitary Engineer, Certified Member American Association of Engineers. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. ix + 248, with 146 figures.) Price 15*s*. net.

A Manual of Practical Anatomy. A Guide to the Dissection of the Human Body. By Thomas Walmsley, Professor of Anatomy, Queen's University of Belfast. In three parts. Part III. The Head and Neck. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. viii + 272, with 94 illustrations.) Price 10*s*. 6*d*. net.

Production Engineering and Cost Keeping. By William R. Basset and Johnson Heywood, of Miller, Franklin, Basset & Co. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. iv + 311.) Price 17*s*. 6*d*.

Traité pratique en Navigation aerienne. Par M. A. B. Duval, L. Hébrard, and M. Laurent-Eynac. Paris: Gauthier-Villars et Cie, 1922. (Pp. vi + 60, with 102 figures.)

Automobile Laboratory Manual. Projects for the Study of Engines, Carburettors, Electrical Systems and Mechanisms, their Construction, Operation, Adjustment, and Repair. By Frederick F. Good, A.M., Instructor in the School of Practical Arts and in the School of Education, Columbia University, New York City. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. xiii + 186, with 88 figures.) Price 7*s*. 6*d*. net.

Steam-engine Principles and Practice. By Terrell Croft, Editor, Consulting Engineer, Directing Engineer, Terrell Croft Engineering Co. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. xiii + 513, with 547 figures.) Price 17*s*. 6*d*. net.

The Marine Power Plant. By Laurence B. Chapman, Professor of Naval Architecture, Lehigh University. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. vii + 320, with 112 figures.)

Standard Handbook for Electrical Engineers. Prepared by a Staff of Specialists. Frank F. Fowle, S.B., Editor-in-Chief, Consulting Electrical Engineer, Member American Institute of Electrical Engineers. Fifth edition, thoroughly revised. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. xviii + 2137.)

Materials of Construction. Prepared for the Extension Division of the University of Wisconsin. By H. E. Pulver, B.S., C.E. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. xviii + 318, with 106 figures.) Price 15*s*. net.

Direction and Position Finding by Wireless. By R. Keen, B.Eng. (Hons.), Sheffield, A.M.I.E.E. London: The Wireless Press, Limited, 12 Henrietta Street, Strand, E.C.2; New York: Wireless Press, Inc., 326 Broadway, 1922. (Pp. 376, with 250 photographs and diagrams.) Price 9*s*. net.

The House of the Indo-Europeans. By Harold H. Bender, Professor of Indo-Germanic Philology in Princeton University. Princeton: Princeton University Press; London: Oxford University Press, 1922. (Pp. 57.) Price 4*s*. 6*d*. net.

Discours et Mélanges. By Emile Picard, Secrétaire Perpetuel de l'Académie des Sciences. Paris: Gauthier-Villars, 1922. (Pp. iv + 291.) Price 10 frs.

Essays by Divers Hands, being the Transactions of the Royal Society of Literature of the United Kingdom. New Series. Vol. II. Edited by William Ralph Inge. London: Oxford University Press, 1922. (Pp. ix + 151.)

Practical Accounting for General Contractors. By H. D. Grant. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. ix + 254.) Price 15*s*. net.

Miracles and the New Psychology. A Study in the Healing Miracles of the New Testament. By E. R. Micklem, M.A., B.Litt. London: Oxford University Press, 1922. (Pp. 1543.) Price 7*s*. 6*d*. net.

The Supremacy of Spirit. By C. A. Richardson, M.A. London: Kegan Paul, Trench, Trubner & Co., 68 Carter Lane, E.C., 1922. (Pp. viii + 159.) Price 5*s*. net.

American Fuels. In Two Volumes. By Raymond Foss Bacon, Ph.D., Sc.D., and William Allen Hamor, M.A. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. Vol. I, ix + 628, with 135 figures; Vol. II, vi+629–1257, with 248 figures.) Price 60*s*. net.

Factory Storekeeping. For Control and Storage of Materials. By Henry H. Farquhar, Assistant Professor of Industrial Management, Harvard Graduate School of Business Administration, Consulting Management Engineer. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. xi + 182.)

The Subject Index to Periodicals, 1917–1919. Issued by the Library Association. K. Science and Technology. London: The Library Association, Stapley House, 33 Bloomsbury Square, W.C.1, September 1922. (Pp. 555.) Price 35*s*. net.

Architectural Drawing. By Wooster Bard Field, Architect, Assistant Professor of Engineering Drawing, the Ohio State University. With an Introduction and Article on Lettering by Thomas E. French. New York: The McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. ix + 161, with 84 plates.) Price 20*s.* net.

Beyond the Pleasure Principle. By Sigm. Freud, M.D., LL.D., Authorised Translation from the Second German Edition, by C. J. M. Hubback. London and Vienna: The International Psycho-Analytical Press, 1922. (Pp. 90.) Price 6*s.* net.

Remembering and Forgetting. By T. H. Pear, M.A., B.Sc., Professor of Psychology in the University of Manchester. London: Methuen & Co., 36 Essex Street, W.C. (Pp. xii + 242, with 9 diagrams.) Price 7*s.* 6*d.* net.

An Introduction to the Psychology of Education. By James Drever, M.A., B.Sc., D.Phil. London: Edward Arnold & Co., 1922. (Pp. viii+ 227.) Price 6*s.* net.

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Pages of Science. Selected and Edited by George Sampson. London: Methuen & Co., 36 Essex Street, W.C. (Pp. 147.) Price 2*s.* net.

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# SCIENCE PROGRESS

## RECENT ADVANCES IN SCIENCE

**PURE MATHEMATICS.** By F. PURYER WHITE, M.A., St. John's College, Cambridge.

*History and Teaching of Mathematics.*—Three articles by Prof. G. A. Miller fall under this head. The first (*School and Society*, **16**, 1922, 449–54), under the title "Disagreeing with the Text-book," gives an interesting account of a course which the author gave during the summer session at the University of Illinois—a critical study of Cajori's *History of Mathematics*. The student was required to find, in a given 25 pages of text, at least one statement with which he did not agree, attention being particularly directed to general statements, such as "Modern higher algebra is especially occupied with the theory of linear transformations." In *School Science and Mathematics* (1922, 715–17) Prof. Miller breaks a further lance with Prof. Cajori on the question of the Greek definition of a tangent-line. The third article (*Scientific Monthly*, **15**, 1922, 512–19) is an elementary account of the ideas underlying the Theory of Groups, and its claim to be, in Poincaré's words, "entire mathematics, divested of its matter and reduced to a pure form."

*Algebra and Analysis.*—If a linear homogeneous transformation $s$ be applied to the variables $x,y$ of a binary form $f(x,y)$, the coefficients $a$ undergo a linear transformation in $n + 1$ variables; these transformations form a group G isomorphic with the linear group of the substitutions $s$. The characterisation of the group G independent of the transformation of the $x,y$ is given by a theorem due to A. Ostrowski (*Math. Ann.*, **79**, 1919, 360–87)—the group G can be defined as the aggregate of all linear transformations of the coefficients which leave the discriminant D of the form $f(x,y)$ unaltered. This theorem cannot, however, be used conversely to characterise the discriminant among the invariants of $f$. We have, in fact, the theorem that every invariant of the form has no further linear transformation beyond those of the group G, except, for $n$ even, the quadrinvariant. This result is given in a recent paper by A. Ostrowski and I. Schur (*Math. Zs.*, **31,** 1922, 81–105).

Sir Thomas Muir (*Proc. R.S. Edin.*, **42,** 1922, 242–7) simplifies and so brings out the real significance of a theorem of Frobenius' on an aggregate of products of minors of a rectangular array.

H. Stenzel (*Math. Zs.*, **15,** 1922, 1–25) investigates the problem of finding the most general matrix X which satisfies the equation $CX = XC'$, where C is a given square matrix of $n$ rows. This is equivalent to finding the most general symmetrical and skew matrices satisfying the equation. The author gives them explicitly and obtains conditions for C in order that their determinants shall not be zero; he also finds necessary and sufficient conditions for the representation of a matrix as the product of two symmetrical, of two skew, or of a symmetrical and a skew matrix.

R. Mehmke (*Crelle*, **152,** 1922, 33–9) generalises the work of K. Böhm on the product of matrices.

W. H. Young (*Proc. L.M.S.*, **21,** 1922, 75–94, 161–90) continues his investigations on the transformation theory of double integrals, showing in particular that practically the formula for an area is true in all the cases in which the double integral of the Jacobian is known to exist.

The first rigorous proof of Cauchy's Theorem without the use of a double integral was given by Malmsten in 1865; Mittag-Leffler later (1873) gave a simpler and more direct proof which also included Laurent's Theorem and required fewer assumptions for the function than did Cauchy's. He now (*Crelle*, **152,** 1922, 1–5; *Arkiv för Mat.*, **17,** 1922, No. 6) returns to the subject, analysing the conditions of the various proofs and pointing out that the assumptions of Goursat's proof of 1884 are not identical with, do not include nor are included by his own.

A. Kienast (*Crelle*, **152,** 1922, 109–19) considers the representation of analytic functions by means of definite integrals in connection with their asymptotic expansions.

It was shown by Eisenstein in 1852 that if an algebraic function can be expanded as a power series with *rational* coefficients, these coefficients will in general be *integers*, or, more precisely, a necessary condition for the series

$$f(z) = \frac{s_0}{t_0} + \frac{s_1}{t_1}z + \ldots + \frac{s_n}{t_n}z_n + \ldots$$

to represent an algebraic function is that a positive integer T can be found so that

$$f(\mathrm{T}z) - f(0) = \frac{s\mathrm{T}}{t_1}z + \ldots + \frac{s\mathrm{T}_n{}^n}{t_n}z^n + \ldots$$

has integer coefficients, *i.e.* $t_n$ is a factor of $T^n$. This condition is clearly not sufficient; for example, the series

$$z + z^2 + z^6 + \ldots + z^{n!} + \ldots$$

does not represent an algebraic function, the circumference of the unit circle being a natural boundary for the function. But there are classes of functions for which the condition is sufficient; such are (1) hypergeometric functions (Errera), (2) functions whose derivatives are rational functions (Pólya), (3) meromorphic functions (Borel), or more generally single-valued functions with only isolated singularities (Pólya). In cases (2) and (3) the functions satisfying the conditions will be rational functions. Of recent years a good deal of work has been done, notably by Borel, Pólya, and Carlson, on functions which can be represented by power series with integer coefficients without being rational functions. Suppose we have a simply connected region D in the complex $z$-plane, containing only inner points and containing the point $z=0$, can we find an analytic function $f(z)$, which is not a rational function, expressible by a power series with integer coefficients, which is uniform and has only isolated singularities in D? The answer to this question has been given by G. Pólya (*Proc. L.M.S.*, **21**, 1922, 22–38; see also a summary in *Jahresber. d. Math. Ver.*, **31**, 1922, 107–55). The domain D can be conformly represented upon a circle in the $w$-plane with the point $z=0$ corresponding to the centre of the circle. If we add the condition that the magnification $\left|\frac{dw}{dz}\right|$ is unity for this point, then the radius of the circle $\rho$ will be uniquely determined. Pólya's result is that if $\rho \leqslant 1$ such a non-rational function can be found, but that if $\rho > 1$, the function must be rational. As a corollary it follows that if $\rho = 1$, then the circle $|z| < \frac{1}{4}$ belongs to D, a result that had been proved by Szegö. Also, if C is a curve with no double points containing $z=0$, and the interior and exterior be conformally represented respectively by $|w| < \rho_1$ and $|w| > \rho_2$, with $w=0$ and $\infty$ corresponding to $z=0$ and $\infty$, and the magnifications unity at these points, then $\rho_1 \leqslant \rho_2$. A special case is that if a power series with integer coefficients converges in unit circle it is either a rational function or else its region of existence is limited by the circle of convergence; a theorem conjectured in 1916 by Pólya and proved by Carlson (*Math. Zs.*, **9**, 1921, 1–13; compare also Szegö, *Math. Ann.*, **87**, 1922, 103–7). Pólya's proof is interesting as it employs theories which at first sight seem wholly disconnected. The first is Kronecker's conditions (1881) for a power series $a_0 + a_1z + a_2z^2 + \ldots$ to represent a rational function, namely that only a finite number of the determinants

$a_0 \begin{vmatrix} a_0 & a_1 \\ a_1 & a_2 \end{vmatrix} \begin{vmatrix} a_0 & a_1 & a_2 \\ a_1 & a_2 & a_3 \\ a_2 & a_3 & a_4 \end{vmatrix}$ . . . should be different from zero. If the $a$'s are to be integers, these determinants $A_n$ will also be integers, and it will simply be necessary to have $\lim_{n \to \infty} A_n = O$. It will be noticed that the same would be true if the $a$'s were integers in an imaginary quadratic field, and the word "integer" can be taken in this extended sense in the theorem. The next step is the introduction of the Tschebyscheff polynomials, which for a given degree differ as little as possible from zero in a given region. Faber (*Crelle*, **150**, 1920, 70–106) showed how conformal representation could be used to find the order of magnitude of such polynomials, and it is thus that conformal representation comes into the theorem.

Allied to this work is that of G. Szegö (*Math. Ann.*, **87**, 1922, 90–111; *Sitzungsber. Berlin*, 1922, 88–91) on power series with only a finite number of different coefficients. Such a series either represents a rational function or is not continuable beyond unit circle. In the first case the coefficients $a_n$, from a certain $n$ on, are periodic and the function is equal to a polynomial divided by $1 - z^m$. See also a paper by Ostrowski (*Sitz. Berlin*, 1921, 557–65) on power series with an infinite number of vanishing coefficients.

The zeros of the Tschebyscheff polynomials, and other polynomials which like them arise from minimum conditions, have been investigated by L. Féjer (*Math. Ann.*, **85**, 1922, 41–8). He starts from the proposition that if we have a point set P in the finite part of a plane, which is either closed or consists of a finite number of points, we can always find a point B which is nearer to any point of P than A is to the same point, provided that A lies outside the convex envelope of P. If $g_n(p)$ is the value of a polynomial of the $n$th degree at any point $p$ of P, then $|g_n(p)|$ has a maximum which may be called the T-divergence (Abweichung, écart). The Tschebyscheff polynomial of degree $n$ for P is defined by the inequality $\text{Max}\,|T_n(p)| \leqslant \text{Max}\,|g_n(p)|$; and Fejer proves that the zeros of $T_n$ lie in the convex envelope of P, provided that P contains at least $n$ points. As a particular case, if P is the straight line-segment $-1 \leqslant x \leqslant 1$, then the roots are all real and in this interval. Other types of divergence may be defined to give other polynomials, for example, the Bessel-divergence, defined for a finite number of points as $\{g(p_1)^2 + \ldots + g(p_k)^2\}/k$, or for the points of a rectifiable curve of length $l$ as $\frac{1}{l}\int |g(p)|^2 ds$, and similar conclusions are arrived at for the zeros. An extension of some of this work is given by M. Fekete and J. L. v. Neumann

(*Jahresber. d. Math. Ver.*, **31**, 1922, 125–38), who show that if P be symmetrical to the real axis and we construct the circles on the joins of symmetrical points, then every non-real root of a T-polynomial, with real coefficients, lies inside or on one of these circles, an extension similar to that of Jensen to Gauss's theorem on the zeros of the derivative of a polynomial.

If a polynomial have only real zeros, all its derivatives have only real zeros. If an analytical function is the limit of polynomials with only real zeros, it belongs to a well-defined class of integral functions and none of its derivatives have unreal zeros. What other functions have this property?

G. Pólya (*Math. Zs.*, **12**, 1922, 36–60) gives a partial answer to this question, confining himself to (1) rational functions and (2) integral functions of finite genus which have only a finite number of zeros. He proves the following theorems:

I. If R($z$) is a rational fraction, the number of unreal zeros of $R^n(z)$ tends to infinity with $n$ unless either (1) R has only one finite pole (of any order) or (2) R has only two finite poles which are symmetrical with regard to the real axis. In case (1) the total number of zeros of R is bounded, and in (2), if R takes real values for real values of $z$, the number of unreal zeros of R ($z$) is the same from a definite value of $n$ on.

II. If P($z$) and Q($z$) are polynomials and Q (0) = 0, and we put $G(z) = P(z)\, e^{Q(z)}$, then the number of unreal zeros of $G^n(z)$ tends to infinity with $n$ unless either (1) Q($z$) is of degree one, or (2) Q($z$) is of degree two and equals $bz - cz^2$, $b$ being real and $c$ positive. In case (1) the total number of zeros is bounded, and in case (2), if G takes real values for real $z$, the number of unreal zeros never increases with $n$.

These theorems are particular cases of more general ones:

III. If F($z$) is a meromorphic function, we form the enumerable aggregate of zeros of F($z$), . . . $F^n(z)$ . . . The number of limit-points depends only on the position of the poles of F($z$) and not on their multiplicity. A point $z$ is a limit-point only if the two nearest poles are at equal distances.

We can get a geometrical description of the limit-points. If $a$ is a pole of F($z$) we call the " region of action " of $a$ the points $z$ which are nearer to $a$ than to any other pole of F($z$). If $a$,$b$ are two poles, the common points of their two regions lie in the straight line bisecting $ab$ at right angles. The region of $a$ is the inside of a convex polygon, which may extend to infinity and in this case may have an infinite number of sides. For $\wp$ ($z$) the regions form fundamental regions and are centrally symmetrical hexagons with three pairs of equal and parallel sides. In III the point set is identical with the set of points of the boundaries of the regions of the poles of F($z$).

In the region of $a$ take a point $z$ and develop F($z$) as a power series about it. Then there is one singular point $a$ on the boundary of the region of convergence. But if $a$ is a limit-point there is more than one singular point on the boundary.

A particular example is $1/(1 + z^2)$, for which the zeros of $R^n(z)$ are the points $z = \cot r\pi/(n + 1)$, $(r = 1, 2. \ . \ . \ n)$.

IV. If $P(z)$, $Q(z)$ are polynomials, $Q(z) = bz^q + \ . \ . \ . + b_q$, $b \neq 0$, $q \geqslant 2$, and $G(z) = P(z)\, e^{Q(z)}$, then the limit-points depend only on $q$ and on the two highest coefficients of Q, $b$ and $b_1$. They are the points of two half-rays from $z = -b_1/qb$, dividing the plane into $q$ equal angles, *i.e.* are parallel to the (vector) roots of $bz^q + 1 = 0$.

An example of this, given by Markoff, is $exp(-z^2)$, the zeros of the derivatives being the zeros of Hermite's polynomials, which can be found as close as we like to any point of the real axis.

See also Ålander (*Arkiv*, **14**, 1920, No. 23), who deals with integral functions of genera 2, 3, 4, 5.

Weierstrass, in a letter to Schwarz in 1875 (*Ges. Werke*, ii, p. 235), remarked: "Je mehr ich über die Prinzipien der Funktionentheorie nachdenke—und ich tue dies unablässig—um so fester wird meine Uberzeugung, dass diese auf dem Fundamente algebraischer Wahrheiten aufgebaut werden muss." He himself carried this out in his lectures on Abel's Transcendentals (*Ges. Werke*, iv). R. König (*Math. Zs.*, **15**, 1922, 26–65), taking this as his motto, proceeds to develop the theory of Riemann's transcendentals, which include Abel's as a particular case, in particular as regards that part of Weierstrass's lectures which deals with the fundamental function $H(xy, x'y')$. The fruitfulness of the theory shows itself in the discovery of a complete series of "interchange" theorems, which include those of Abel, Weierstrass, and Fuchs; the development of these is, however, postponed to a later paper.

Among the literary remains of Gauss is a fragment on the multiplication of lemniscate functions for the number 7; having completed this, K. Schwering (*Crelle*, **152**, 1922, 40–8) investigates the more difficult problem of division. See also G. B. Mathews (*Proc. L.M.S.*, **14**, 1915, 464–6).

Poincaré and others have investigated the form of the integral curves of the differential equation

$$[kx + ly + f(x,y)]dy = [mx + ny + \phi(x,y)]dx$$

near the origin, where $f(x,y)$ and $\phi(x,y)$ are power series beginning with terms at least of the second degree. If $kn - lm \neq 0$, the integral curves approximate to those of the simpler equation

$$(kx + ly)dy = (mx + ny)dx,$$

and it is easy to obtain conditions for the origin to be a node (Knotenpunkt, nœud), a saddle-point (Sattelpunkt, col), a winding-point (Strudelpunkt, foyer), or a vortex-point (Wirbelpunkt, centre). A summary of these results, with references, is given by H. Liebmann in the *Encyklopädie Math. Wiss.*, III, D.8, 507. O. Perron (*Math. Zs.*, **31**, 1922, 121–46) investigates the rather more general problem in which $f(x,y)$, $\phi(x,y)$ are not assumed to be power series, but merely to be small relatively to the linear terms. The integration can no longer be performed by means of Poincaré's series, but the same types arise, with the addition of one new one, in which there are infinitely many closed integral curves and also integral curves which wind infinitely many times about the origin, having two closed integral curves as asymptotic lines. In the present memoir, however, he confines himself to three cases, for which (1) all the curves have a common tangent at the origin, except one which has a different tangent; (2) one curve passes in each direction through the origin; (3) all the curves without exception have a common tangent at the origin and there is one which is crossed by all the others.

If a linear differential equation can be put into the form

$$\left\{\phi\left(x\frac{d}{dx}\right) - x\psi\left(x\frac{d}{dx}\right)\right\}y = 0,$$

it will have in general a series solution

$$y = x^a + \frac{\psi(a)}{\phi(a+1)}x^{a+1} + \frac{\psi(a)\psi(a+1)}{\phi(a+1)\phi(a+2)}x^{a+2} + \ldots,$$

where the initial exponent $a$ is a root of the indicial equation $\phi(a) = 0$. T. W. Chaundy (*Proc. L.M.S.*, **21**, 1922, 214–34) applies a similar method to partial differential equations of the type

$$\left[\phi\left(x\frac{d}{dx_1}, x_2\frac{d}{dx_2}, \ldots\right) - x_1^{\alpha}x_2^{\beta}\ldots\psi\left(x_1\frac{d}{dx_1}, x_2\frac{d}{dx_2}, \ldots\right)\right]z = 0.$$

He obtains a solution which has as many arbitrary elements as we ought to expect in the general solution, and which may be made to coincide with the general solution in those cases in which this has been otherwise obtained. He is not able to show, however, that the solutions obtained are actually in all cases general solutions. The method is expounded by the consideration of particular examples.

Progress has been made towards Goldbach's theorem on the representation of an even number as the sum or difference of two odd primes in a series of memoirs by P. Stäckel [*Sitz. Heidelberg*, 1917, Ab. 15; 1918, Ab. 2, 14; 1922, Ab. 10 (with W. Weinreich)]. He makes use of "gap-numbers," which arise in the process of finding primes by means of the sieve of Eratosthenes. If $p_r$ be the $r$th odd prime ($p_1 = 3$), then the gap-numbers of the $r$th rank are all the odd numbers which are prime to $p_1, p_2 \ldots p_r$, including 1, but not these $p$'s; they consist, in order, of 1, $p_{r+1}$, then prime numbers up to $p^2_{r+1}$, and only after this include composite numbers. They appear to be more tractable than the primes themselves. The first part of the last paper quoted contains results on the expression of an even number as the sum or difference of such gap-numbers; the second part contains guesses suggested thereby for primes, which are tested experimentally by calculation. They include asymptotic formulæ for the number of prime pairs of difference $2\delta$ of which the first lies in the interval $2n$, 1, and for the number of Goldbach representations. This work should be compared with similar empirical work by N. M. Shah and B. M. Wilson (*Proc. Camb. Phil. Soc.*, **19**, 1918, 228–54); see also a paper by R. Haussner (*Jahresber. d. Math. Ver.*, **31**, 1922, 115–24).

E. Kamke (*Crelle*, **152**, 1922, 30–2) has a note on the simultaneous decomposition of integers into first and $n$th powers.

B. M. Wilson (*Proc. L.M.S.*, **21**, 1922, 235–55; *Proc. Camb. Phil. Soc.*, **21**, 1922, 140–9) proves and extends some theorems of Ramanujan connected with the sums of the $r$th powers of the divisors of an integer $n$.

R. Sturm (*Crelle*, **152**, 1922, 90–8 and 99–108) has a couple of interesting papers dealing with geometrical problems of maxima and minima on the lines of his book *Maxima und Minima in der elementaren Geometrie* (Leipzig, 1910), which is perhaps not sufficiently well known. He investigates in the first the greatest tetrahedron, given the areas of the four faces; and in the second the two problems—(1) Given two lines and a point in a plane, to find the line through the point for which the segment cut off is a minimum; (2) given three planes and a point (or a line), to find the plane of the sheaf (or pencil) which is cut by the given planes in the triangle of minimum area. Neither of these problems can be reduced to one of the second degree, *i.e.* they cannot be solved by ruler and compasses.

The problem of the catenary in the calculus of variations can be generalised if we suppose that, one end remaining fixed, the other $x_0$, $y_0$ is variable in a vertical plane, the length of the string between the points being not a fixed quantity $l$, but $l - \phi(x_0, y_0)$, $\phi$ being a given function. Queen Dido's Problem, of the maximum area enclosed between a string of given length and a given boundary, can be generalised in a similar way (G. Weyl, *Crelle*, **152**, 1922, 76–98).

*Geometry.*—A recent number of the *Proceedings of the Cambridge Philosophical Society* contains three papers by pupils of Prof. H. F. Baker. Miss H. G. Telling (*Proc. Camb. Phil. Soc.*, **21**, 1922, 249–61) gives a geometrical treatment of the theory of apolar quadrics, Reye's papers on the subject being partly analytical. Given a fundamental quadric envelope $\Sigma$, self-conjugate hexads, defined by six points such that the plane of any three is conjugate to the plane of the remaining three, self-conjugate pentads, five points such that the line joining any two contains the pole of the other three, and self-polar tetrads, four points such that each is the pole of the plane of the other three, are introduced. The properties of twisted cubics passing through the vertices of self-conjugate hexads are considered, and it is shown that (i) if a twisted cubic be such that a self-conjugate hexad, with respect to $\Sigma$, can be inscribed therein, then an infinite number of such hexads can be inscribed therein ; (ii) if a twisted cubic be such that a self-polar tetrahedron can be inscribed therein, then an infinite number of such tetrahedra and also of self-conjugate pentads and hexads can be inscribed therein ; (iii) if a twisted cubic be such that a self-conjugate hexad can be described therein, then self-conjugate pentads and self-polar tetrads can be described therein. Similar propositions are shown to be true in the case of quadrics.

C. G. F. James (*ibid.*, 150–78) discusses the analytical representation of congruences of conics by means of matrices.

F. P. White (*ibid.*, 216–27) examines curves and surfaces which are generated from projective systems of hyperplanes in space of four dimensions.

The fundamental properties of the twisted sextic curve which is the complete intersection of a quadric and a cubic surface have up till now only been investigated by means of the periods of Abelian functions of genus 4, and it seems likely that purely geometrical methods will lag a long way behind analytical ones in problems of this kind. An important advance has, however, been made recently by W. P. Milne (*Proc. L.M.S.*, **21**, 1922, 373–80), who establishes synthetically the properties of the sextactic quadrics and tritangent planes of *one* of the 255 systems which Clebsch showed to exist for the quadri-cubic curve. If the curve be the complete intersection of the quadric $\Gamma_2$ and the cubic surface $\Gamma_3$, and $S_2$ be a sextactic quadric, then he proves that the vertex of one of the cones of the pencil $S_2 \Gamma_2$ lies on the twisted cubic through the six points of contact. He then considers the four-nodal cubic surfaces which contain the curve, and shows that the quadric cones, into two of which the tangent cones to one such surface from any point of it break up, form a complete set of sextactic cones of the same system ; also the quadrics which contain the points of contact of any two sextactic cones of the same system with the curve are the pencils of quadrics determined by $\Gamma_2$ and the quadrics which contain any two twisted cubics lying upon the four-nodal cubic surface. The 28 surfaces of the system which break up into pairs of tritangent planes are found to correspond to the 28 bitangents of a plane quartic curve, the section of the quartic surface which is the locus of points whose polar planes with respect to a cubic surface $C_3$ touch $\Gamma_2$ by the plane $\gamma$ for which the four-nodal cubic is the polo-cubic surface with respect to $C_3$; the complete configuration of the 28 tritangent plane pairs of the same system may thus be deduced.

The two inflexional tangents at a point on a surface have in general three intersections with the surface at the point; there are, however, an infinite number of inflexional tangents with more than three-point contact. Enumerative results in this connection were obtained by Salmon for the *general* surface of order $n$; H. W. E. Jung proposes to call such tangents Salmon tangents, and determines (*Crelle*, **152**, 1922, 11–29) (1) the number of places where both inflexional tangents are Salmon tangents, and (2) the number of Salmon tangents which meet an arbitrary line, in terms of the arithmetical genus of the surface, the genera of a plane section and of the tangent cone from an arbitrary point, the Zeuthen-Segre invariant, the class of a plane section, and the order and class of the surface.

O. Haupt (*Crelle*, **152**, 1922, 6–10) defines asymptotes of plane curves in a wider sense and obtains sufficient conditions for asymptotic tangents and asymptotic parabolas.

Brunn in 1889 obtained an inequality between the areas of three parallel sections of a convex body, $F_1$, $F_2$, $F_3$, of which $F_2$ lies between the others and divides the distance between them in the ratio $t : (1 - t)$, in the form

$$\sqrt{F_2} \geq (1 - t)\sqrt{F_1} + t\sqrt{F_3},$$

the equality sign holding only when $F_1$ and $F_3$ are similar and similarly situated and the part of the convex body lying between them consists of the frustum of a cone which joins them. Further proofs have been given by Minkowski and Blaschke. K. Zindler (*Math. Zs.*, **31**, 1922, 106–10) gives a proof in the elementary special case of convex polyhedra, without limit considerations.

The generalisation to three dimensions of the equiangular spiral, namely the surface which cuts the rays of a sheaf at the same angle, has been studied by G. Scheffers (1902), who gave a general method of generating such surfaces and determined their lines of curvature, and by G. Landsberg (1909), who obtained the two fundamental quadratic forms. There are two recent papers on the subject by R. Baldus (*Math. Zs.*, **15**, 1922, 147–58; *Berichte Heidelberg*, 1921, Abh. 10), who gives a series of geometrical properties of the surface, and by considering also imaginary surfaces obtains those which are algebraic. Equiangular spirals which are at the same time algebraic curves have been considered by the same author (*Archiv d. Math.*, **28**, 1920, 102–11); there is, for instance, the well-known curious theorem that if a rectangular hyperbola be a parabola it is also an equiangular spiral.

**ASTRONOMY.** By H. Spencer Jones, M.A., B.Sc., Chief Assistant, Royal Observatory, Greenwich.

*The Relativity Displacement of Spectral Lines.*—One of the crucial tests of Einstein's Theory of Relativity depends upon the establishment of the existence of a slight displacement towards the red of the spectral lines of a massive body such as a star as compared with those from a terrestrial source. At present, the investigation of this test must be confined to the solar spectrum, as the wave-lengths of stellar lines are not known with the required accuracy. Even in the case of the Sun, it is a matter of extreme difficulty to establish beyond possibility of doubt whether the required displacement is or is not absent. This difficulty arises from the smallness of the effect which it is required to determine and from the presence of a number of other disturbing causes such as pressure displacements, etc., whose magnitudes are comparable with that of the Einstein effect. Nevertheless, several claims to have established the existence of the displacements required by Einstein have been made, and some of the supporters of the theory have jumped to the conclusion that the matter can be regarded as settled. In particular, the experiments of Grebe and Bachem in Germany were held by many in that country to have proved that there is a displacement of the solar lines of the amount required by Einstein.

It is well, therefore, that these claims should be examined impartially and the present state of the situation made clear. This has been done by St. John, whose conclusions appear in the last report of the Mount Wilson Observatory. The following is a summary of St. John's survey:

Pérot found that there was a sun-arc displacement of the amount required by theory. His investigation was based on the line $\lambda 4197$, the unsymmetrical head of the second band of cyanogen. In obtaining his result he applied corrections for an assumed downward movement in the solar atmosphere and for a negative pressure shift of the cyanogen band lines, the latter being approximately equal in magnitude to the shift required by relativity. Dr. Birge, using two lines in the $\lambda 3883$ cyanogen band, and applying corrections for an upward movement in the solar atmosphere, but assuming that there was no pressure shift, also finds a displacement in accordance with the theory. Grebe and Bachem also used the cyanogen lines, but assumed no radial movement and no pressure shift; they, however, applied a correction for a supposed asymmetry of the arc lines. They also deduced approximately the Einstein effect. At Mount Wilson it is found that the pressure shift of the cyanogen band is much smaller than assumed by Pérot: it is also concluded, from a detailed study of the band, that as there is an extensive overlapping of the lines of the different series, and as there are changes of relative intensity with temperature, the cyanogen band is not suitable for a definitive test of the theory.

Pérot has also used the magnesium line λ5172. His observed sun-arc shift was corrected for a centripetal movement in the solar atmosphere of 1·57 km. per second. After reducing the arc wave-length to zero pressure, he again found a displacement of the amount required by theory. St. John points out, however, that this magnesium line is subject to a marked pole-effect, and that three independent investigations at Mount Wilson have failed to show the centripetal motion assumed by Pérot. "Fabry and Buisson find that the differences between the arc wave-lengths of iron reduced to vacuum and the wave-lengths at the sun's centre are of the order of the Einstein effect. They conclude that the differences, sun *minus* arc, are perfectly interpreted by assuming the Einstein effect to be the sole cause of the displacement of the Fraunhofer lines. They assume zero pressure in the solar atmosphere, but disregard the limb-centre shifts, which they formerly referred to an increase in pressure of 7 atmospheres in passing from the centre to the limb, and which, if taken into account, would give a displacement in excess of the Einstein requirement. Pérot applies a large correction, 0·027A, for centripetal motion, and finds the difference between the wave-lengths at the limb and the arc in vacuum to agree with the Einstein effect. Fabry and Buisson apply no correction for radial movement of the solar vapours, and find the differences between the wave-lengths at the centre and the arc in vacuum to agree with the Einstein requirement, but not the differences between the wave-lengths at the limb and the arc."

It will be seen that the present state of the question is an extremely unsatisfactory one, different and mutually inconsistent corrections having been applied by various investigators. As St. John states, the problem must be envisaged as a whole and not in detached portions, and it is intended to carry out at Mount Wilson an extensive programme on sun-arc displacements, including observations at centre and limb and covering the widest possible range in wave-length and line-intensity, so that a large amount of reliable data will be accumulated for statistical discussion. It is only in this way that it will be possible to disentangle the Einstein effect from the other disturbing factors and to determine accurately its amount. The process will necessarily be a slow one, but the result may be accepted with confidence.

*The Boundary of a Star.*—It is well known that there is a gradual dissipation of an atmosphere owing to the gradual diffusion of molecules from its outer boundary. The rate of loss is greater the higher the temperature and the weaker the gravitational field, as more molecules then acquire a sufficiently large velocity to have a chance of escaping. From this point of view, it is at first sight difficult to understand the existence of large giant stars. Such stars have an extremely low density, a fairly high temperature, and are so large that the value of the gravitational attraction at their outer boundary is very small. It might be thought, therefore, that the atmospheres of such stars would be rapidly dissipated and that, since these stars are gaseous, they would gradually be completely dissipated. In a paper read before the British Association at its last meeting by A. A. Milne, it was shown that this argument is fallacious. He shows that the critical velocity of escape depends not on the acceleration due to gravity at the boundary, but on the gravitational potential there. Even for a giant star, the potential at the boundary is large compared with that at the boundary of the Moon, so that the dissipation should be far slower for a giant star than for the Moon. Milne's investigation, in fact, shows that it will be quite inappreciable for all stars. He finds that there is a fairly narrow layer in the atmosphere of the star in which most of the dissipation occurs. At this height, the density is such as to correspond to a mean free path $l$ given by

$$l/r = A/q,$$

where $q = mV/RT$, $r$ is the radius of the star and $A$ is a numerical constant whose value may be taken to be about 3. From this formula it is deduced that the mean free path for helium at the escape level in the earth's atmosphere is about 130 kms. corresponding to a height of about 600 kms. For hydrogen in the Sun's atmosphere, $l = 400$ kms., and for a giant star of the same mass as the Sun at a temperature of 3,000°, $l = 1 \cdot 5 \times 10^6$ kms.

It is apparent that the loss by escape will be highest for stars with a low value of $q$. For giant stars, $q$ is much smaller than for dwarfs, and for giants of given mass it decreases with the temperature. It is shown that it has an absolute minimum when the radiation pressure is one-fifth of the total pressure. Assuming a mean molecular mass of 4, this occurs when the mass is 0·85 of the Sun's mass. It is a striking fact that this is approximately the average mass of a star. The conclusion is that the most favourably placed of all stars for loss by diffusion to be appreciable is a giant star of about the mass of the Sun.

It is further pointed out that the surface gravitational potential for giants is small compared with that for a dwarf star, and consequently that it is highly unlikely that there are any stars for which measurement of the Einstein effect is at all accessible as compared with the Sun.

*The Spectroscopic Determination of Stellar Parallaxes.*—Our knowledge of stellar parallaxes has been considerably revolutionised of late years by the spectroscopic methods of determination which have been developed mainly by Adams and others at the Mount Wilson Observatory. The method, which has been previously explained in these notes, depends on determining the absolute magnitude of the star from measurements of the relative intensities of certain lines in its spectrum which are particularly sensitive to luminosity. The method as originally developed was restricted to stars which are redder than those of type A, as the A-type stars do not show the large variations in the intensities of the lines which appear in the redder stars. On the other hand, it is found that they show considerable differences in the appearances of the lines, which are sharp in some stars and diffuse in others. This characteristic has been made the basis of a method of obtaining the parallaxes of A-type stars by Adams and Joy (*Astroph. Jour.*, **56**, 242, 1922). Using stars whose absolute magnitudes are accurately known, it is found that there is a good correlation between magnitude and spectrum, the magnitude being brighter the earlier the spectral type and brighter for stars having spectra with sharp lines than for those having spectra with diffuse lines. Extending the method to all A-type stars of known spectral type and parallax, it was found that there was an average difference of only $\pm 0''\cdot0077$ for 82 parallaxes determined by group motion, and of $\pm 0''\cdot0131$ for 104 trigonometric parallaxes. The method is to be further developed and refined, but meanwhile a preliminary list of the parallaxes of 544 stars of types B7 to F2 is given by Adams and Joy in the paper referred to.

The preliminary results of an investigation by Edwards at the Norman Lockyer Observatory of the spectroscopic parallaxes of B-type stars is given in *M.N., R.A.S.*, **13**, 47, 1922. In this investigation the intensities of all measurable lines were referred to the average intensity of the hydrogen lines as a standard. In this way a certain number of lines were found whose intensities varied with either type or absolute magnitude. Such lines were compared with neighbouring unaffected lines by means of a wedge photometer and the variations were standardised by using stars of known absolute magnitude. In the paper is given a preliminary list of 49 parallaxes of stars of B-type. It is thus seen that with these extensions of the original method, it becomes possible to determine the parallaxes by indirect means of stars of any type except exceptional stars such as those of the very earliest type.

**METEOROLOGY.** By E. V. Newnham, B.Sc., Meteorological Office, London.

*Hurricanes and Tropical Revolving Storms*, by Mrs. E. V. Newnham, M.Sc. (*continued*).—In the January number of Science Progress a brief summary was given of the portion of this memoir which deals with the observed characteristics and geographical distribution of cyclones throughout the world. The theoretical side of the subject will now be considered.

In his introductory note entitled " The Birth and Death of Cyclones," Sir Napier Shaw points out that the tropical hurricanes, together with the smaller " tornadoes," are generally admitted to be examples of travelling vortices, and to these may be added, as a result of his own researches, the small " secondary " depressions that occur so frequently in the prevailing westerly winds of temperate latitudes, and which, he has shown, travel with approximately the same speed as that of the winds in their immediate neighbourhood. Any theory, however, which purports to explain the mode of origin and the structure of tropical hurricanes must take into account the fact that these often pass into temperate latitudes, and on entering the zone of prevailing westerly winds are indistinguishable from the large primary " depressions " of these regions, to which the " secondaries " just referred to are related in much the same way that a satellite is related to its primary. Considerations of continuity would lead one to expect that if the tropical hurricane is a vortex, then these primary depressions will also have the same structure, seeing that the transition from a tropical hurricane to a temperate depression is a gradual one, and the resemblance between the two types of storm is considerable. On this point, however, some divergence of opinion exists among meteorologists, the structure of a temperate depression suggested by Prof. V. Bjerknes showing lines of discontinuity of a non-circular shape by no means suggestive at first sight of vortex motion. Sir Napier Shaw maintains, however, that at suitable heights, roughly between 4,000 metres and 8,000 metres, the temperate cyclone is actually a symmetrical whirl, for at these levels the correlation between pressure and temperature is so high as to exclude the likelihood, perhaps even the possibility, of appreciable asymmetry. That asymmetry exists, however, at lower levels he is fully prepared to admit. Further evidence in support of the vortex theory is furnished by the velocity of translation of the extra-tropical cyclones, which velocity is on the average in close agreement with that of the circumpolar circulation of westerly winds at a height of 4,000 metres, as computed by Tessereinc de Bort, and shows a seasonal variation similar to that of these winds. Tropical hurricanes, as well as "secondary depressions" and tornadoes, all admitted to be in most instances examples of vortex motion, show likewise a tendency to move with the prevailing winds in the regions of their occurrence. We may assume, therefore, that the phenomenon to be explained is the initiation of a violent circular vortex in the Doldrums, and the maintenance of such a vortex practically unchanged throughout its sojourn in the tropics, also on certain occasions its expansion and diminution of intensity on entering higher latitudes, where it may continue for days or even weeks when circumstances are favourable.

Sir Napier Shaw, after pointing out the fact that tropical hurricanes originate in regions where the equatorial belt of easterly winds blow over conspicuously warm sea-water, passes to a discussion of the detailed manner in which a whirl may be initiated. His remarks on this part of the subject are of particular interest, and may be quoted here :

"The selection by tropical cyclones of the localities of hottest sea-water for their place of birth or nurture is certainly suggestive of convection from the surface as their cause ; and the recent investigation of the upper air enables us to say that conditions have been ascertained which, if brought into juxtaposition, could produce certain results of the proper order of magnitude for tropical cyclones. For example, from the soundings of air at Batavia on the island of Java, we obtain an average or normal representation of the lapse of temperature with height in the equatorial region, and we know also from Neuhoff's diagram [1] and equation the effect upon temperature of adiabatic changes of pressure in the case of air saturated with water vapour at, for example, 300° C. (Absolute). We can set out these side by side, and we see at once that air saturated with water vapour at 300° a. would be in unstable equilibrium at the surface at Batavia. If it began to rise it would not find itself at the same temperature with its surroundings, and therefore not permanently in equilibrium, until the level of 15 kilometres had been reached, and only then if we suppose it to be loaded with its condensed water as drops. After they had fallen out, further height would be required to bring the density of the air to that of its environment. There is nothing to excite surprise in this result,

[1] Meteorological Glossary, Meteorological Office, London, p. 16.

because we know from the results for temperature for equatorial regions that convection does go on there up to a level of 17 kilometres before the stratosphere is reached.

"We can go further and consider what would be the pressure at the surface if a column of air some 10 or 12 miles in diameter, for example, were replaced by the air which was saturated at the surface and thrust up into the heights. We can compute the pressure-difference between an interior column of air so defined and its environment, neglecting the humidity of the air, in the computation of the density, but allowing for it in the change of temperature. It appears that in these circumstances the difference of pressure between the exterior column and the environment would be as much as 81 millibars at the surface, and gradually diminish from that to 8 m.b. at the level of 10 kilometres and to nothing at the level of 15 kilometres. We can set out all these facts respecting saturated air and its possible relation to its environment in a table as follows :

NORMAL PRESSURES AND TEMPERATURES IN EQUATORIAL AIR (BATAVIA) WITH THE TEMPERATURES OF AIR SATURATED WITH WATER VAPOUR AT 300 a., AND REDUCED WITHOUT ANY SUPPLY OF HEAT TO THE PRESSURE AT THE UPPERMOST LEVEL, WITH THE DIFFERENCES OF PRESSURE AT DIFFERENT LEVELS BETWEEN THE NORMAL AIR AND THE COLUMN OF SATURATED AIR.

| Height. | Normal Air. Batavia. | | Saturated Air changed adiabatically to same pressure at 15 km. | | Pressure differences between the two columns. |
|---|---|---|---|---|---|
| | Pressure. | Temperature. | Temperature. | Pressure. | |
| Kilometres. | Millibars. | Degrees Cent. Absolute. | Degrees Cent. Absolute. | Millibars. | Millibars. |
| 15 | 128 | 198 | 199 | 128 | 0 |
| 14 | 152 | 203 | 209 | 151 | 1 |
| 12 | 209 | 219 | 229 | 207 | 2 |
| 10 | 283 | 235 | 248 | 275 | 8 |
| 8 | 376 | 251 | 263 | 360 | 16 |
| 6 | 491 | 265 | 275 | [illegible] | 27 |
| 4 | 632 | 279 | 284 | 591 | 41 |
| 2 | 803 | 290 | 292 | 745 | 58 |
| 1 | 903 | 295 | 296 | 835 | 68 |
| 0 | 1,012 | 300 | 300 | 931 | 81 |

"It may be noted that this form of instability is very much dependent upon the temperature of saturation of the air, and it is therefore limited to regions where the air is not only very hot, but also very moist. It should also be noted that the difference of temperature between the rising air and its environment reaches a maximum of 13 a. at 10 kilometres. We can see from this table that under suitable conditions the air of the surface is capable of rising to the heights which are actually characterised by convection in the equatorial regions, and that, if a hollow column could be filled with it and protected by a rigid wall from its environment, it would give rise to a difference of pressure at the surface of the same order as those found between the centres and margins of tropical cyclones, and rather larger than is generally recorded."

The writer then considers the manner in which convection might be expected to achieve the results just described. He points out that in the atmosphere convection apparently proceeds either by "threads" or "bubbles." The "thread" process is evidently operative on an ordinary sunny day in dry regions and results in the heating of a considerable thickness of air near the surface in such a manner as to produce a vertical gradient of temperature appropriate for dry air which is in convective equilibrium. With the "bubble" type of convection, on the other hand, a large mass of warm air is pushed up by the convergence of the air beneath it. It must be supposed that as it moves upwards a certain amount of the surrounding air is dragged with it, at the expense of some of the ascensional force. By the passage of a succession of bubbles in this manner the air originally over the area will have been removed; the external air will have converged towards a central axis, and the beginning of revolving fluid will have been set up.

"Continued further, the same process will continue to remove the internal portion of the revolving column until the rotation has become sufficiently developed to resist further convergence towards the centre. By that time, with the aid of the original vorticity of the earth's rotation, we shall have reached at all levels the condition of a simple vortex with a ring of maximum velocity, within which the pressure is kept low through the continual removal of air by what may be called the scouring action of the ascending bubbles. The axis then becomes practically unapproachable because the air that aims towards it is always deviated from its course. It takes part in the circulation and misses the convergence. So we get a dynamical system of great stability which admits air to the region of the axis only along the immediate surface, where the motion cannot reach the limit of protection, because it is retarded by friction.

"So far we have a warm core with an environment the temperature of which, except at the very bottom, is governed by the dynamical cooling due to the convergence towards the axis. If the air of the environment contains sufficient moisture, cloud will form; and with the formation of cloud instability is probable, which will cause further condensation and possibly abundant rainfall outside the original column. All this can occur while the whole system is being developed in the easterly wind, and it moves with the wind towards the region where the surface is still warmer, and, consequently, the surface air also becomes warmer; the dynamical process of scouring the central column is continued. But there will come a time when the supply of hot moist air at the surface is exhausted, and then the passage of the air through the column by ascent from the bottom must cease; the air can only rise until its temperature is the same as that of the cooled environment. When that stage has been reached, any hot air remaining in the column will be ejected at the top by the convergence from the sides, and we shall have obtained a dynamical system consisting of a vortex with a ring of maximum velocity of finite diameter and its interior protected from further invasion, except at the bottom, by the velocity of rotation, so that it can only be affected by the creeping of air or other material into the interior along the bottom. The temperature distribution will be that produced by convergence of the environment towards the axis; the whole effect of the convection, originally due to the heated and saturated surface air, will have been to cause the removal of the air from along the axis, which Lord Rayleigh's exposition requires for the formation of a vortex of revolving fluid. Thus the high temperature of the interior is merely a temporary incident in the formation of a cyclonic vortex: by the time the vortex is developed as a dynamical system the core is cold; there is no longer any convection in it; it becomes a comparatively small area protected from the ordinary vicissitudes of weather by the enormous momentum of a vortex with a high rate of spin, represented by the very violent winds of a certain ring, but extending in less violent form over a vast area."

Air can, however, enter the system near the surface, where the rotary velocity and consequently the momentum is reduced by friction: "So long as the surface air which is dragged into the interior in this way is warm enough to cause local convection in the region to which it is carried, additional energy is conveyed to the dynamical system; but when a layer of cold air is attacked the convection only extends until the temperature is reduced sufficiently for the air to remain in dynamical equilibrium with its surroundings, and the addition of mass to the interior, instead of helping to scour the column, increases the pressure there. The ring of maximum velocity is, therefore, enlarged, but its velocity is diminished. The reverse of the process of formation is followed. As this process is continued, the central pressure continually increases, and the ring of maximum velocity is widened and depressed.

This apparently happens as the cyclone passes into the region of the prevailing westerlies, and is continued as the journey proceeds. If, in the course of its travels, the cyclone should find its base supplied with polar air, its energy is necessarily paralysed. Though the death is a lingering one, it must die when the velocity of the vast mass is sufficiently reduced and its area correspondingly extended. Its existence might be prolonged somewhat if it could make use of the convective properties of the equatorial air in juxtaposition with the polar front, but it would certainly be starved out of existence if it had to feed exclusively upon polar air."

If the theory outlined above is correct, then we must regard convection as the operative force in the creation of both tropical and extra-tropical cyclones, but not in the simple manner generally assumed hitherto. Whether correct or not, the theory is well worth studying in the original memoir, as many of the arguments there brought forward have of necessity been abridged, or even omitted, in this short summary.

Dr. Harold Jeffreys adds (pp. 234–5) some further remarks of a general nature to the theoretical discussion of the subject. The two principal theories that are held as to the cause of tropical cyclones are, he points out, the Convectional and the Counter Current theories. The convectional theory has just been dealt with at considerable length. The counter current theory supposes that the whirls are eddies formed by the interaction of extensive opposed wind currents, in a manner analogous to that in which eddies are formed in a mill pond. It is difficult on the convectional theory to explain why one place rather than another in an extensive area of hot moist air should be selected as the place of origin of a storm. It may be, however, that the truth is contained in a combination of the two theories, and that this difficulty may be overcome by supposing that the conflict between opposed currents is the earliest stage in the initiation of a whirl and that convection continues and intensifies the motion in the manner described by Sir Napier Shaw. In support of this theory Dr. Jeffreys suggests that the South Atlantic, which is the only tropical ocean in which cyclones are not experienced, is also the only one which is not flanked by opposite wind currents.

**PHYSICS.** By J. Rice, University, Liverpool.

*Recent Work on the Molecular Diffraction of Light.*—It is many years now since the late Lord Rayleigh first brought the subject of molecular diffraction into importance by his well-known papers on the blue light of the sky which results from the scattering of sunlight by the gases of the atmosphere. Since that time there have been a large number of researches, theoretical and experimental, on this question, not only in connection with gaseous and vaporous media, but also for solids and liquids. It is proposed in this note briefly to review the present situation.

When light passes through a gaseous medium, each molecule becomes a centre of secondary disturbance. In the direction of propagation of the primary wave, the secondary waves emitted by all the molecules in a given layer are in identical phase, although the phases will be retarded behind the phase of the primary wave by an amount which corresponds to the retardation associated with the passage of light through a refractive medium, and can be related to the index of refraction of the gas. In other directions than that of the primary wave, the phases of the scattered waves do not stand in an invariable relation to one another, since the molecules are distributed at random in the volume. Hence, to find the intensity of the scattered light in any direction we sum, not the amplitudes of the waves scattered by individual molecules, but the squares of the amplitudes, or the intensities. By mathematical reasoning we find in this way a relation between the intensity of the emerging beam deprived of the scattered light and the index of refraction. In fact the beam is reduced in intensity after traversing a distance $x$ through the gas in the ratio $e^{-\kappa x}$, where

$$\kappa = 32\pi^3(\mu - 1)^2/3N\lambda^4.$$

$\mu$ is the index of refraction, $\lambda$ the wave-length, and there are N molecules per unit volume.

This formula of Rayleigh's has stood the test of experimental observation very well over wide ranges of pressure and density. The method of deriving it has been criticised by Larmor, but it would appear that the criticisms can be well met. Rayleigh's original memoir appeared in vol. xlvii of the *Phil. Mag.* (1899), and fairly recent papers by Rayleigh and Larmor discussing the theoretical points raised can be found in the *Phil. Mag.*, December 1918 and January 1919. It would seem that the assumption of random phases for the light scattered from individual molecules (which is necessary if we are to add *intensities* and not *amplitudes*) is justifiable if the probability that a given molecule is found within a small specified volume is independent of the presence of any other molecules, i.e. if the volume occupied by the gas is a sufficiently large multiple of the total volume of the molecules—in short, if there is reasonable agreement with Boyle's law.

According to Lord Rayleigh not only should the intensity of the scattered light be proportional to $(\mu - 1)^2$, but the light scattered in a direction perpendicular to the incident beam should be completely polarised. As regards the intensity, experimental work by the present Lord Rayleigh (then R. J. Strutt), published in the *P.R.S.* A **94** (1918), verified this within the limits of his experimental error ; but Cabannes in the *Annales de Physique*, Tome xv (1920), showed that there are discrepancies not covered by experimental error. Strutt and Cabannes also noticed that the polarisation of the scattered light was imperfect, and the late Lord Rayleigh himself offered an explanation of this, viz. that the molecules are not spherically symmetrical, but have three principal axes of symmetry oriented at random [*Phil. Mag.*, **35** (1918)]. Mathematical reasoning shows that the scattered light should be proportional not to $(\mu - 1)^2/N\lambda^4$ merely, but to

$$(\mu-1)^2/N\lambda^4 \,.\, (6 + 6\rho)/(6-7\rho)$$

where $\rho$ is given by

$$\rho=(A^2+B^2+C^2-AB-BC-CA)/[3(A^2+B^2+C^2)+2(AB+BC+CA)]$$

In this A, B, C are three parameters characteristic of the three axes of the molecule and the wave-length. The work of Cabannes lends support to this formula.

In his first paper Lord Rayleigh stated quite clearly that his theory of molecular scattering is not applicable in the case of highly condensed media such as dense vapours, liquids, and solids ; here the molecules possess only a restricted freedom of movement ; their distribution cannot be regarded as a simple random arrangement. One cannot equate the energy scattered by a volume of liquid or solid to the sum of the energies scattered by individual molecules, since the phases of the secondary wavelets are no longer uncorrelated and interference must take place. In fact Strutt has shown [*P.R.S.*, A **95** (1919)] that liquid ether scatters much less light than it should in comparison with the vapour on consideration of relative density alone. A theory of scattering for liquids and solids has been supplied by Smoluchowski and Einstein [*Ann. der Physik*, **25** (1908) and **33** (1910)], based on the so-called "theory of fluctuations." Scattering, in their view, is not due to individual particles, but to small local variations of density arising from the thermal agitation of the molecules. By reasoning based on statistical mechanics and thermodynamics it can be shown the mean square of the fluctuations of the density $\rho$ of a substance occupying volume V is $RT\beta\rho^2/NV$, where N is the number of molecules in a gram-molecule and $\beta$ is the compressibility. At right-angles to the incident light the intensity of scattered light is given by

$$(\Delta\epsilon)^2\pi^2V^2/2r^2\lambda^4$$

at distance $r$ from the volume V, where $\Delta\epsilon$ is the fluctuation of the dielectric constant $\epsilon$ corresponding to a fluctuation $\Delta\rho$ of density. It is assumed that $\epsilon$ and $\rho$ are connected by the Lorentz formula

$$(\epsilon - 1)/(\epsilon + 2)\rho = \text{constant}.$$

and so $(\Delta\epsilon)^2$ can be obtained in terms of $(\Delta\rho)^2$, whose mean value is given above. After some steps it is shown that the intensity of the light scattered by unit volume at right-angles is

$$\pi^2/18 \,.\, RT\beta/N \,.\, (\mu^2 - 1)^2(\mu^2 + 2)^2/\lambda^4$$

where $\mu^2$ is written for $\epsilon$.

In the case of gases this formula degenerates to Rayleigh's.

This formula explains the reason for the remarkable opalescence which appears in a vapour near the critical point ; for in such a case the value $\beta$ is relatively very large. It has been quantitatively tested by Keesom [*Ann. der Physik*, **35** (1911)] for ethylene in this opalescent condition, with very satisfactory results. Some experiments by Raman have shown that in the case of water the molecular scattering is about 158 times that of dust-free air ; the Einstein-Smoluchowski formula yields the result that it should be above 140. This discrepancy may be due to the difficulty of obtaining a liquid entirely free from motes, which magnify the scattering effect ; or to the anisotropy of the molecules referred to above. If the calculated result is affected by the factor $(6 + 6\rho)/(6 - 7\rho)$ used by Cabannes and mentioned above, it increases it to 160 from 140, in very good agreement with the observed value. Also some recent experiments of W. H. Martin [*Jour. of Phys. Chem.*, **24** (1920)] on the relative scattering of ether, alcohol, benzene, and toluene to water, agree moderately well with the Einstein-Smoluchowski formula combined with the factor $(6 + 6\rho)/(6 - 7\rho)$ involved in the anisotropy of the molecules. Some work of the present Lord Rayleigh's [*P.R.S.*, **95** (1919)] on scattering by quartz is also in fair agreement with the formula if the fluctuations are calculated on the view that they arise from the thermal agitation of the atoms in the crystalline space-lattice. (This thermal motion of the space-lattice is the starting-point of Debye's well-known theoretical work on the variation of intensity of X-ray reflection with temperature, which has been applied with success to X-ray experimental work.) Considering the striking success of the formula for such different states of matter, it is surprising to find that it breaks down signally for gases under high pressure. For example, carbon dioxide at 21° C. and 60 atmospheres has been found by Strutt to scatter 102 times as much as at atmospheric pressure. The formula yields the result that it should be at least 800 times.

The importance of pursuing these researches has led Prof.

Raman, of the University of Calcutta, and his pupils to undertake a systematic study of this field. Two papers have already appeared in the *P.R.S.* for last April and November, and a comprehensive outline of the present state of the subject is given in a small monograph by Professor Raman, "Molecular Diffraction of Light," published recently by the Calcutta University Press. In this monograph Raman advances the view that the partial breakdown of the Einstein-Smoluchowski formula is due to the inadequacy of the Maxwell equations of the electromagnetic field when applied to emission or absorption of energy from atoms or molecules. He suggests that these phenomena may yield some support to the very revolutionary form of the Quantum hypothesis put forward by Einstein (going considerably beyond Planck's own conservative views) that the energy of a beam of light is not distributed continuously *in space*, but consists of a finite number of localised indivisible energy-bundles or "quanta" capable of being *absorbed* or emitted only as wholes.[1] It must be said that the model introduced by Bohr for the atom, with its stationary states, is more in accord with this view of both discontinuous absorption and emission, than with Planck's reservation concerning continuous absorption, which was actually introduced by him so as to accommodate his special form of the Quantum hypothesis to the Maxwell equations.

**PHYSICAL CHEMISTRY.** By W. E. Garner, M.Sc., University College, London.

*A New Element.*—The search for missing elements has been rewarded by a number of discoveries, based on spectroscopic and X-ray evidence, which make it probable that the number of vacant places in the periodic table will be considerably diminished in the near future. The number of elements with an atomic weight less than that of uranium, which remain to be discovered, is limited to those with the atomic numbers 43, 61, 72, 75, 85, and 87. There now appears no doubt as to the existence of an element, between lutecium and tantalum, with the atomic number 72. Dauvillier (*C.R.*, 1922, **174**, 1347–9), and Hevesy and Coster (*Nature*, 1923, **111**, 79) claim to have demonstrated the existence of an element with this atomic number. The material in which the new element was detected was very different in the two cases; the former made use of a rare earth preparation of Urbain's, and the latter made their discovery with a zirconium mineral.

Urbain (*C.R.*, 1911, **152**, 141–3), during the fractionation of

[1] As is well known, J. J. Thomson entertains views of a similar nature as to the propagation of light.

the nitrates of lutecium from the gadolinium earths, obtained the oxide of a new element, which gave a characteristic line spectrum. Very little is known of its chemical properties, except that it is probably a rare earth. The volatility of its anhydrous chloride and the strength of its base are intermediate between the corresponding properties of the compounds of lutecium and scandium. To this element Urbain gave the name Celtium (Ct). Dauvillier, while studying the *L*-series of lutecium and ytterbium, discovered two feeble lines, $\beta_2 = 1319{\cdot}4$, and $a_1 = 1561{\cdot}8$, which agreed with an atomic number 72 for the new element. Urbain (*C.R.*, 1922, **174**, 1349–51) considers that Dauvillier's work definitely establishes the position of celtium in the periodic table.

J. Maria Eder (*Sitzungsb. Akad. Wiss. Wien*, 1922, **131**, 199–298), in the course of the examination of the spectra of a number of terbium, dysprosium, and gadolinium fractions, found a new element between the terbium and dysprosium fractions which gave characteristic and well-defined lines not previously observed for any other substance. The element was named welsium. Its position in the periodic table is not stated, but it is possible that it occupies the vacant space between neodymium and samarium (atomic number 61).

Hevesy and Coster have measured six of the *L*-series of a missing element which occurs in zirconium minerals, $L\text{-}a_1 = 1565{\cdot}5$; $a_2 = 1576$; $\beta_1 = 1371{\cdot}4$; $\beta_2 = 1323{\cdot}7$; $\beta_3 = 1350{\cdot}2$; $\gamma_1 = 1177$ X-$\mu$. $L\text{-}a_1$ and $L\text{-}a_2$ lie almost exactly in the places of the $Ka_1$ and $a_2$ of zirconium, but the difficulty of measurement was overcome by maintaining the tension of the tube between the critical tension of the zirconium *K* lines, and the *L* lines of the missing element. All of the lines were within 1 $X$-$\mu$ of the figures interpolated from the spectra of the two elements immediately before and after the element with atomic number 72. On the other hand, Dauvillier's values differed from the theoretical by more than 4 $X$-$\mu$. It was estimated that the new element appeared in zirconium minerals to the extent of 0·01 to 0·1 per cent. In one specimen about 1 per cent. of the new element was present. This suggests that this new element is a homologue of titanium and zirconium, and hence should be tetravalent. According to the Bohr theory, an element with an atomic number 72 should possess one more electron in the 5 and 6 quantum orbits than the rare earths. Since the latter are tervalent, it would therefore be expected that the new element would be tetravalent. On this account, the authors consider that the *L*-series obtained by them and Dauvillier cannot be those of a rare earth element, and that the rare earth element discovered by Urbain must possess another atomic number. One awaits with interest the publication of the chemical properties of the new element, which should settle this point. Meanwhile Scott, at a recent meeting of the Chemical Society, has communicated the discovery of a new oxide from a ferruginous sand from New Zealand. It is an extremely refractive substance, and not readily attacked by concentrated sulphuric acid or fused caustic soda. It is slowly attacked by bisulphate of potash, giving an orange melt. Heated with hydrofluoric acid and the requisite quantity of potassium carbonate, it gives a double fluoride, analogous to potassium fluortitanate. The equivalent was determined by conversion of the double fluoride into oxide by ignition with sulphuric acid, and subsequent extraction with water. The mean of two results gave an approximate atomic weight of 175. The chemical behaviour of the element made it perfectly clear that it is not a member of the rare earth group, and that it is a homologue of titanium and zirconium.

*The Photochemistry of Hydrogen-Chlorine Gas Mixtures.*—A number of papers have appeared recently on this still unsolved photochemical problem. In one of these, Wendt, Landauer, and Ewing (*J.A.C.S.*, 1922, **44**, 2377–82) have directed their attention to an observation of Draper that the induction period in this reaction can be eliminated by a preliminary exposure of the chlorine to ultra-violet light. That the activation of the chlorine can be brought about in this manner has been confirmed by these authors, who have also shown that the chlorine gas retains a portion of its activity even after twenty-four hours. This active form of chlorine cannot consist of the free atoms, since from evidence of the behaviour of other gases in the monatomic state, it would be expected that free chlorine atoms would recombine in a short time. If $Cl_3$ were the active form, the reaction should occur on mixing active chlorine with hydrogen in the dark. The authors find that even with intense pre-illumination no hydrochloric acid is produced. The possibility of the active form being $Cl_3$ is thus eliminated. Wendt ascribes the activation rather to the destruction of negative catalysts than to any activation of the chlorine itself.

Weigert (*Z. Elektrochem.*, 1922, **28**, 456–8) has studied another aspect of the problem. Draper observed that immediately after exposure of a mixture of hydrogen and chlorine to light, an increase in volume occurred which was due either to an increase in the number of molecules by dissociation, or to the liberation of heat. Weigert shows that the phenomenon is a photochemical after-effect. On illumination of a gas mixture by the light from an electric spark, a wave of expansion spread out from the illuminated region which synchronised with a movement of the surface of a water manometer in contact with the gas. By photographing the region near the point of entrance of the light, with the aid of a second spark, he showed that no appreciable expansion occurred until $\frac{1}{100}$ second after illumination. The disturbance was at a maximum in $\frac{1}{40}$ second, and had entirely disappeared in $\frac{1}{10}$ second. The conclusion is drawn that the reaction between hydrogen and chlorine reaches a maximum $\frac{1}{40}$ second after illumination by a chain-like mechanism similar to that postulated by Bodenstein and Nernst. Since one quantum of energy converts $10^6$ molecules of the mixture into hydrochloric acid, it can be shown that each element in the chain takes $10^{-8}$ seconds to be completed. This interval of time occurs frequently in modern theory of chemical change. An extension of this investigation should prove of considerable value in the elucidation of the processes occurring during the induction period.

*Physical Chemistry of Foodstuffs.*—An important advance has been made by Paul, Dietzel, and Taufel (*Z. Elektrochem.*, 1922, **28**, 435–6) in the application of the methods of psycho-physics to determine the relationship between acid taste and hydrogen-ion concentration. By means of these methods, and the introduction of new terminology, the measurement of acid taste has been placed on a quantitative basis. Molecular acidity, for example, is defined as the number of mols of hydrochloric acid, dissolved in a fixed volume of water, which tastes as acid as one mol of the acid substance dissolved in the same volume of water. The molecular acidity is determined not entirely by the hydrogen-ion concentration, but mainly by the capacity of the acid substance to yield its reserve of hydrogen ions to the tongue. The nature of the anion influences to some extent the acid taste of a substance. It is possible to arrange acid substances in a series of increasing molecular acidities, thus carbonic acid, potassium hydrogen tartrate, acetic acid, lactic acid, acetyl lactic acid, hydrochloric acid, and tartaric acid form such a series. Carbonic acid possesses the weakest, and tartaric acid the strongest, acid taste in this series. This arrangement is not in agreement with the dissociation constants of the acids. Thus the two acids, acetyl lactic and tartaric acids, although possessing very similar dissociation constants, possess very different acidities. Many analogies appear to exist between the two properties, specific acidity and specific sweetness. Both increase, for example, with concentration in a similar manner. This relationship between two of the taste qualities suggests that similar regularities may be found between these and the salt, and bitter qualities of substances.

*The Adsorption and Fluorescent Spectra of Aromatic Hydro-*

*carbons.*—Victor Henri (*Journ. Phys. et Radium*, 1922, [vi], **3**, 181–211; and *C.R.*, 1922, **175**, 421) has effected a considerable improvement in the technique of the measurement of the adsorption bands of organic substances. The ultraviolet spectrum of benzene has been measured at vapour pressures ranging from 0·01 to 65 mm. At the low pressures, the adsorption bands are resolved into a series of narrow bands about 0·15Å apart, and these fuse into wider bands on passing a certain limiting pressure. More than 350 bands have been counted. It is shown that the adsorption of ultraviolet light by benzene obeys the same laws as the band spectra of simple di- or tri-atomic molecules. The application of the Bohr theory to the band spectra permits of their classification into four series, each band being given by an equation of the form $1/\lambda = A - B + na - (pb + p^2b^1) + a(m^2 - q^2)$, in which A, B, $a$, $b$, $b^1$, and $a$ are constants and $n$, $p$, $m$, and $q$ whole numbers. The coefficients deduced from the results of the ultraviolet absorption may be employed for the calculation of the infrared absorption spectra of benzene. The terms A and B are due to electronic movements and do not enter into the frequency of the infrared adsorption bands, for which a simple formula is deduced, $1/\lambda = an - bp$. The calculated and experimental values are in satisfactory agreement. The ultraviolet spectra of liquid benzene and its solutions, whilst very similar to that of the vapour, show a slight shift towards longer wave lengths. The displacement does not bear any relation to the dielectric constant of the solvent. The fluorescent spectrum of liquid benzene consists of six bands, which are excited by monochromatic light of wave lengths lying between the benzene absorption bands D, E, F, G, and H; the lines corresponding to the $A_1$ and B absorption bands do not excite any fluorescence. The fluorescent bands are displaced towards the red, with respect to the absorption bands.

For naphthalene a similar absorption spectra has been found to that observed with benzene. In all seventeen bands were measured between 3207 and 2563, and one band in the extreme ultraviolet. The absorption curve is displaced towards the red, with respect to that of benzene, and the adsorption is ten times stronger and the number of bands more numerous than in the case of benzene. The influence of the solvent on the spectra of the two substances is the same in both cases.

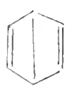
Stewart and Marsh (*Nature*, 1923, **111**, 115) have succeeded in obtaining the luminescence spectrum of benzene, by subjecting benzene vapour to the action of the waves from a Tesla transformer. At low pressures a regular spectrum is obtained, composed of a series of band groups. These emission bands agree almost exactly with the fluorescent and absorption bands of benzene. The Fraunhofer effect has been observed for some of the bands. This is the first time this has been observed for an organic substance of complex structure.

**ORGANIC CHEMISTRY.** By O. L. Brady, D.Sc., F.I.C., University College, London.

*The Structure of Benzene.*—The old problem of the structure of benzene and its derivatives has recently been attracting considerable attention, but, although many ingenious suggestions have been made, the new methods of attack, with the possible exception of the determination of crystal structure by X-rays, have not contributed very much to our previous knowledge. Most, if not all, of the modern investigators have ignored the dynamical formula for benzene first suggested by Collie twenty-five years ago (*Trans. Chem. Soc.*, 1897, **71**, 1013; 1916, **109**, 561), which has the advantage of combining the static formulæ of Kekulé, Dewar, Baeyer, and others, and provides a more rational starting-point for further speculation than these other formulæ. The use of the hexagon as an ideograph by workers in organic chemistry seems to have led investigators to think that a static formula for benzene is very generally accepted, but to those who have worked with benzenoid derivatives the hexagon symbol has usually conveyed much more than a simple structural formula.

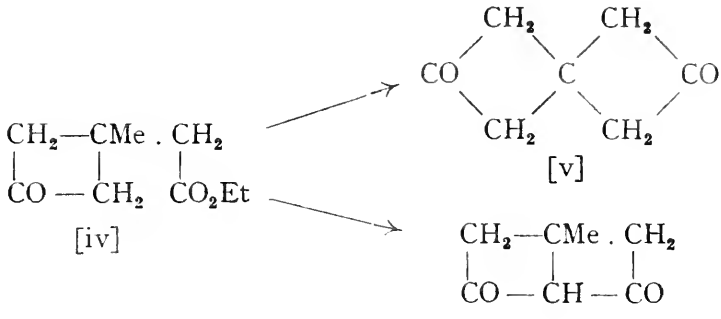
On the experimental side Ingold (*Trans. Chem. Soc.*, 1922, **121**, 1133 and 1143) has, by the synthesis of a benzenoid derivative from an alicyclic compound, brought forward support for the bridged ring formula [ii] of Dewar as an intermediate phase between the two forms of the Kekulé formula [i] and [iii].


[i]


[ii]

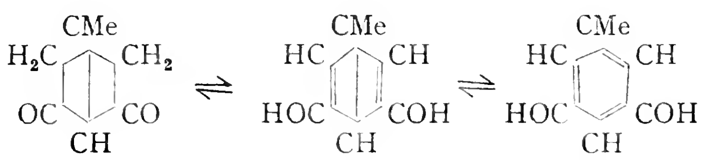

[iii]

The benzenoid compound synthesised was orcinol [viii] and was obtained by a Dieckmann condensation brought about by treating ethyl 3-methylcyclobutan-1-one-3-acetate [iv] in ethereal solution with a suspension of finely divided sodium in benzene. The reaction can take place in two ways, resulting in the formation of either a spiran ketone [v] or a bridged ring ketone [vi], but it has been found that the condensation takes the second course.



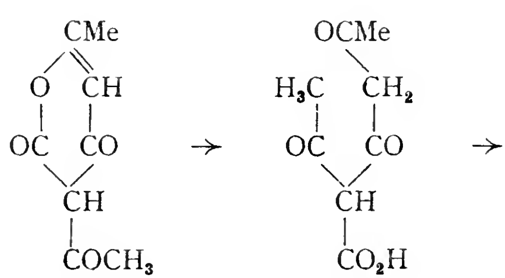
[iv] [v] [vi]

The bridged ring ketone [vi] is the ketonic form of the bridged ring form of orcinol [vii], and the product of the reaction was found to be identical with ordinary orcinol [viii]. The author represents the dynamic change as follows :

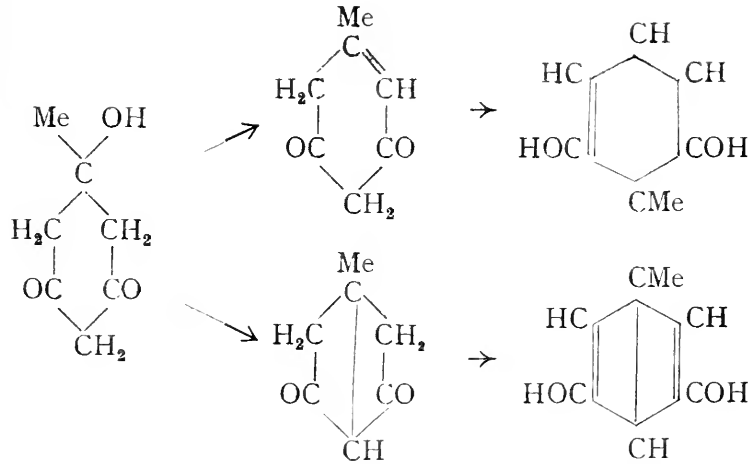


[vi] [vii] [viii]

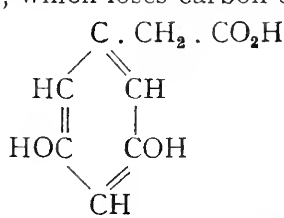
He considers that the synthesis of orcinol from dehydracetic acid [ix] carried out by Collie and Myers (*Trans. Chem. Soc.*, 1893, **63**, 124) can be so represented as to give either the usual Kekulé formula for orcinol or the bridge ring structure, the reaction consisting in the rupture of the lactone ring of dehydracetic acid followed by an internal aldol condensation and loss of carbon dioxide.



[ix] [x]



This suggested mechanism is, however, open to criticism. Ingold assumes that the compound reacts in a keto-form throughout, but as the reaction is brought about by syrupy caustic soda at 150°, an enolic structure seems more rational. Moreover orcinol is probably a secondary product of the reaction, the first product being an acid which Collie and Myers suggest is dihydroxyphenylacetic acid [xi], which loses carbon dioxide on heating to give orcinol.

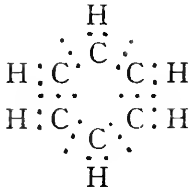


[xi]

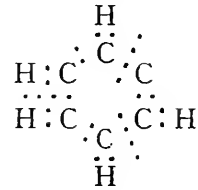
One feels that a reaction of this sort is too little understood at present to be used as evidence one way or other. The author claims that his new synthesis of orcinol is free from ambiguity of this sort, but the recent researches of Thorpe and his co-workers on the phenomenon of ring-chain isomerism suggest that such isomerism is possible though perhaps unlikely in the case of ethyl 3-methylcyclobutan-1-one-3-acetate, the starting material for the synthesis.

The bridged formula as a dynamic isomeride of benzene is applied to the explanation of many of the characteristic reactions of benzenoid compounds, but all these can be similarly explained by the dynamic formula of Collie of which the bridged ring is essentially a phase.

On the speculative side the application of the Lewis-Langmuir theory to the structure of benzene is exciting considerable interest. J. J. Thomson (*Phil. Mag.*, 1921, **41**, 510) suggested that benzene consisted of six cells of eight electrons in contact round a ring; if there is threefold contact between each pair of cells the thirty available electrons are fully utilised, each carbon atom sharing three electrons with those on either side [xii].

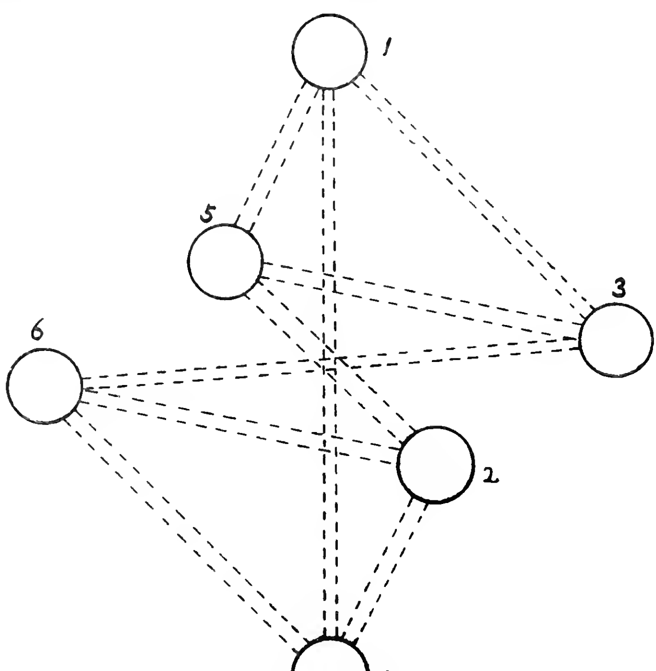


[xii]



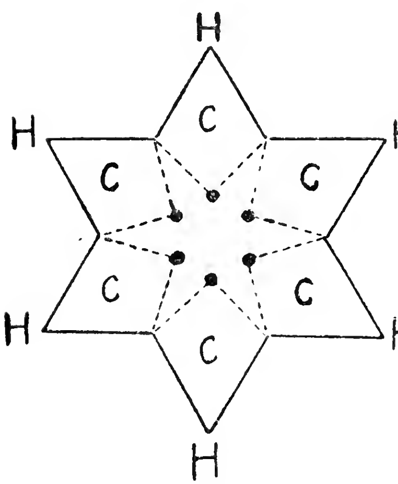
[xiii]

Such a structure corresponds to the centric formula for benzene; the Kekulé formula [xiii] consists of three sets of pairs of cells, the cells in one pair having fourfold contact with each other. but only double contact with a cell in a neighbouring pair. This, however, is little more than a restatement of the older formulæ in a new nomenclature. Fraser (*Trans. Chem. Soc.*, 1922, **121**, 188) has put forward an electronic structure for benzene in which duplets, that is, two electrons held in common corresponding to the "bond" of classical organic chemistry, are shared according to the following method [xiv]:

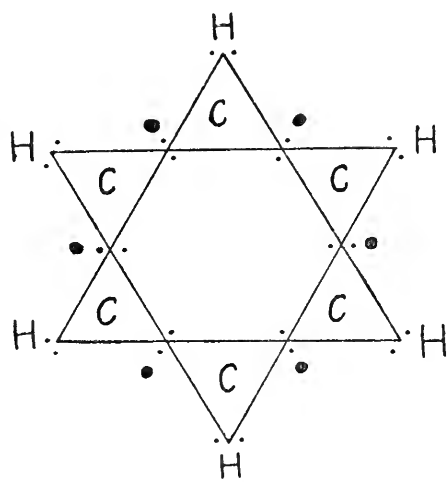



[xiv]

With regard to position (1) position (4) is para, positions (3) and (5) meta, and (2) and (6) ortho. The space formula in which the relative positions of the electrons round the carbon atoms are taken into account is not very clearly explained and is too complicated to be discussed here. The author considers that a static formula for benzene is demanded, but seems to ignore many obvious difficulties of which perhaps the most important is the separation of the ortho-positions. Numerous examples of ring closure with the production of benzenoid derivatives seem to be quite at variance with the suggested structure. Crocker (*J. Amer. Chem. Soc.*, 1922, **44**, 1618) has also applied the Lewis-Langmuir theory to the benzene problem. The original conception of the cubical form of the octet cell when applied to the carbon atom is not consonant with the facts of optical activity, and there seems a general tendency towards the adoption of the tetrahedral form, the electrons being arranged in pairs in spite of certain theoretical objections. A structure for benzene on the lines of the centric formula would be represented as [xv]

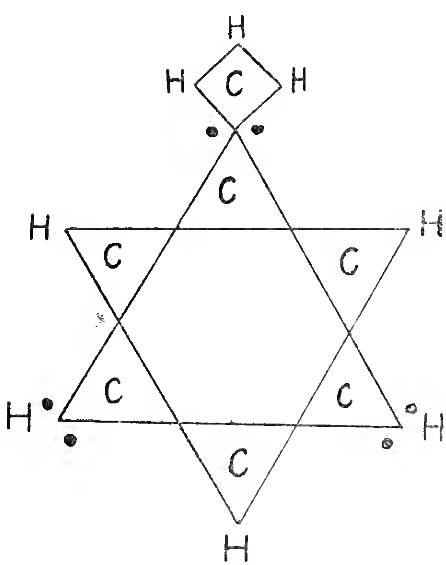


[xv]

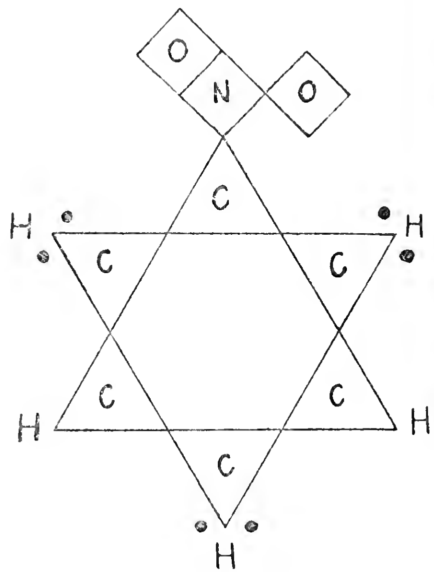


[xvi]

but this involves a violation of the octet principle as each kernel is surrounded by only seven electrons; moreover six electrons relatively close together in the centre of the ring without a positive kernel to hold them are unlikely to form a stable arrangement. Accordingly the author suggests that the electrons are repelled to the outside of the ring, each carbon then sharing a pair of these electrons with the carbons on either side [xvi]. Moreover, it is suggested that the free electrons are vibrating in the plane of the ring alternately pairing with their neighbours. It will be seen that this formula is not greatly different from that originally suggested by J. J. Thomson, it is symmetrical and contains no ethylenic linkages. The author elaborates a theory to explain the phenomena of substitution in the benzene ring based on the influence of the electronic environment of the first substituting group which causes the free electrons on each side of it to pair up. The movement of any two electrons from their mean position in order to pair up will disturb the electrical equilibrium of the system, and the others will move in such a manner as to restore it. Thus in [xvii] and [xviii] the influence of a methyl and nitro-group is indicated. The argument that certain groups



[xvii]

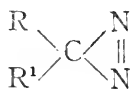


[xviii]

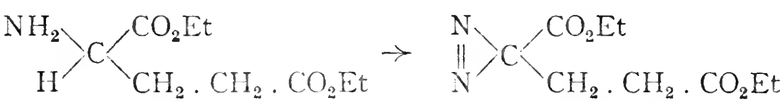
such as methyl should attract the electrons and others such as the nitro should repel them is ingenious, but too long to be given here. The consequence of this arrangement, according to the author, is that the positions occupied by the electrons are to a great extent closed to substitution; hence in [xvii] *o*-*p*-substitution will occur, while in [xviii] *m*-substitution takes place. An attempt is made to explain the fact that *o*- and *p*-substitution in many cases do not take place to an equal degree, but here perhaps the author is less happy. The theory is also applied to other ring structures such as pyridine, thiophene, furane, and pyrrol with considerable success.

The important work of Henri on the absorption spectrum of benzene at low pressures is described in the section dealing with Physical Chemistry in this number, while the study of the crystal structure of some benzenoid compounds was the subject of a special article in the December number of this Journal.

*Optically Active Diazo-compounds.*—Chiles and Noyes (*J. Amer. Chem. Soc.*, 1922, **44,** 1798) have published an important paper on optically active diazo-compounds of the type

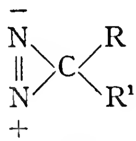


Previously Marvel and Noyes (*J. Amer. Chem. Soc.*, 1920, **42,** 2259) had described unsuccessful attempts to prepare such bodies, and since the publication of this earlier work Levene and Mikeska (*J. Biol. Chem.*, 1921, **45,** 593 ; 1922, **52,** 485) reported that they had obtained diethyl diazosuccinate in an optically active form. The present authors now explain that the lack of success in the earlier experiments was due to the ease with which the compounds racemise and emphasise the necessity of distilling the compounds at very low pressures. The first compound obtained was an active diethyl diazo-glutarate [xx] $[\alpha]_D + 0{\cdot}85°$ to $+ 1{\cdot}86°$ obtained by the usual method from *d*-glutamic ester [xix]

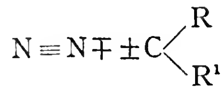


[xix] [xx]

Other active compounds obtained were dimethyl *a*-diazo-glutarate $[\alpha]_D + 0{\cdot}89°$, diethyl *a*-diazosuccinate $[\alpha]_D - 1{\cdot}23°$, ethyl *a*-diazo-*n*-caproate $[\alpha]_D - 1{\cdot}89°$, ethyl *a*-diazo-*n*-caproate $[\alpha]_D + 1{\cdot}84$, and ethyl *a*-diazo-iso-caproate $[\alpha)_D - 1{\cdot}52°$. The fundamental importance of these results has caused the authors to give very careful consideration to possible impurities which might account for the activity, and they have satisfied themselves that it is really due to the diazo-compound. The interpretation of these results is a matter of some difficulty. Chiles and Noyes consider that the Curtius formula [xxi] for these active compounds cannot be reconciled with the ideas of atomic structure and of non-polar valence proposed by Lewis and Langmuir, but that the Thiele formula [xxii] can be so reconciled if it is assumed that the polar valence between an ammonium group and another atom is a definite bond located in a fixed position in the compound



[xxi]



[xxii]

They claim that there is evidence that this is the case. (Compare Potter and Noyes, *J. Amer. Chem. Soc.*, 1915, **37**, 189.)

**GEOLOGY.** By G. W. Tyrrell, F.G.S., A.R.C.S., University, Glasgow.

*Tectonic Geology.*—Prof. A. Wegener's hypothesis of lateral drift as an explanation of the present arrangement of the large land masses of the globe still holds the field as a subject of animated controversy. Early land masses are believed by Wegener to have broken along gigantic rifts, of which the Atlantic Ocean is an example; and the severed portions, floating upon the heavier subjacent stratum of the crust, have drifted farther and farther apart. The former connections are indicated, if not proved, by the amazing correspondences in shape and geological structure between opposite continental masses, as, for example, South America and Africa; and also by the facts of the present world distribution of plants and animals. The hypothesis does away with the necessity for the huge land bridges across the oceans which have been postulated in order to explain the present distribution of life.

The greatest success of Wegener's hypothesis has been in explaining the Mesozoic continent of Gondwanaland, with its widespread glaciation, its fresh water and temperate continental sediments, and its typical Glossopteris flora. Hence it has won some acceptance from South African geologists, especially A. du Toit. The fragments of Gondwanaland are now to be recognised in South Africa, Brazil, Falkland Islands, Antarctica, Australia, and Peninsular India. If these remnants have always been where they are at present, the disappearance of the connecting parts is very hard to explain. According to Wegener it would be a physical impossibility for them to sink into the heavier substrata of the crust. Another great difficulty is to explain the glaciation, the traces of which are found in every part of Gondwanaland. Under the hypothesis of an immense southern continent stretching from Brazil to Australia, and from India to Antarctica, the ice must have spread over enormous areas in equatorial latitudes. If, however, Gondwanaland was originally only a moderately large continent centred in the south temperate zone about the present site of South Africa, there is no more difficulty in comprehending its glaciation than the Pleistocene glaciation of parts of the northern hemisphere, or the present glaciation of Antarctica and Greenland.

This point of view is taken in A. du Toit's elaborate review of the "Carboniferous Glaciation of South Africa" (*Trans. Geol. Soc. S. Africa*, **24**, 1921, pp. 186–227). Wegener's views are also adopted in du Toit's paper on "Land Connections between the Other Continents and South Africa in the Past" (*South African Journ. Sci.*, December 1921, pp. 120–40). The Dwyka ice-sheet, which came into being in the Uralian (Upper Carboniferous), was an extensive body formed by the coalescence of ice radiating from several distinct centres, namely, Namaland, Griqualand West, Transvaal, and Natal. Subsequently to the Triassic Gondwanaland was forcibly disrupted, and the fragments moved apart until they were brought up in the Tertiary against the ring of earth-folds developed in that era.

Mr. P. Lake gives a critical review of Wegener's hypothesis in the *Geol. Mag.* (**59**, 1922, pp. 338–46). Lake points out numerous discrepancies in Wegener's joinings of the land masses, and shows that in many cases Wegener has ignored the geological history of the land masses thus brought into contact. "He [Wegener] has suggested much, he has proved nothing." A like scepticism pervades the discussion on Wegener's hypothesis at the Hull meeting of the British Association (*Nature*, January 6, 1923, pp. 30–1), and Prof. G. A. J. Cole's review (*Nature*, December 16, 1922, pp. 798–801).

An interesting symposium on the topic of isostasy has recently been conducted by the Geological Society of America. The following list of papers published in their *Bulletin* (vol. xxxiii, 1922, pp. 273–410) will give an idea of the nature and range of the subjects discussed: W. Bowie, "Theory of Isostasy—A Geological Problem"; G. R. Putnam, "Condition of the Earth's Crust and the Earlier American Gravity Observations"; H. O. Wood, "Some Considerations touching on Isostasy"; H. F. Reid, "Isostasy and Earth Movements"; J. F. Kemp, "Isostasy and Applied Geology"; Sir Sidney Burrard, "Folding of Mountain Ranges—the Argument from Isostasy"; A. C. Lawson, "Isostatic Compensation considered as a Cause of Thrusting"; A. C. Lane, "Weight of Sedimentary Rocks per Unit Volume"; B. Willis, "Rôle of Isostatic Stress"; H. S. Washington, "Isostasy and Rock Density."

It is only possible here to touch upon a few interesting points in this discussion, as, for example, the connection of isostasy with mountain building. H. F. Reid shows that many great fold-mountain chains are bounded by huge faults, and contain within their limits widespread dissected peneplains which post-date the folding. Hence he believes that the folding took place mainly at low levels, and was succeeded by a period or periods of peneplanation. Subsequent vertical movements uplifted the chains to their present altitude. Thus the objection to the principle of isostasy based on the belief that mountain chains were elevated by horizontal compression is rendered invalid. The larger vertical movements are due to changes in the density of the underlying crust, concerning the cause of which we can only speculate.

H. O. Wood suggests the growth of batholiths as a possible cause of mountain building which can be appealed to quite independently of tangential pressure. He also believes that "the weakening and strengthening of adjacent elements of the outer shell by readjustments brought about by erosion or deposition under effective isostatic control may permit tangential stress to be generated, sustained, and transmitted to weak regions, so as to build mountains, . . . so long as any effective compacting of the interior of the earth continues from any cause."

Sir S. Burrard is now doubtful that the hypothesis of isostasy excludes the hypothesis of the origin of mountains by horizontal folding. He argues that if the excess loads of delta material are automatically compensated in depth (as they are), why should not loads locally accumulated by folding be also compensated ?

From mechanical considerations A. C. Lawson shows that, for a real overthrust, the limiting length of the overthrust prism in the direction of the force applied is between 20 and 30 miles when the thrust plane is nearly horizontal, and about half this amount if the thrust plane dips at 20 degrees. These values agree well with those actually observed in overthrust regions such as north-west Scotland and Scandinavia.

A. C. Lane makes the important suggestion that it is the weight of rock per unit volume that matters in certain geological problems rather than the specific gravity of the rock powder as usually found. In questions of isostasy this is especially the case in computing the weight of crustal columns made up partly of recent water-logged (or oil-logged) deltaic and other sediments.

By a consideration of the average density of igneous rocks within certain large and small regions H. S. Washington shows that the average density of the igneous rocks of a region varies in the opposite sense as the average altitude. This result harmonises with, and corroborates, the theory of isostasy.

The densities were computed from the norms of the average igneous rocks of the various regions. For the United States Washington demonstrates a remarkable correspondence between comagmatic regions and areas of positive or negative gravity anomalies. Since Washington is dealing with compact, almost pore-free, igneous rocks, the considerations emphasised by Lane do not apply.

In his Presidential Address to the Geological Society Dr. R. D. Oldham (*Quart. Journ. Geol. Soc.*, **78**, pt. i, 1922, pp. lv–lxviii) deals with the cause and character of earthquakes. He shows that the rate of growth of strain which produces an earthquake may not be so slow as sometimes imagined, but may take place in a period of the order of a few months. The faults with which earthquakes are usually associated are not the " causes " of the earthquakes, but merely serve to localise and control the distribution and intensity of the seismic phenomena. In many cases tectonic processes cannot be the cause of the strain, and Dr. Oldham suggests that rapid changes of volume in the sub-crust, due to sudden changes in modes of mineral aggregation, may be the cause of many earthquakes. For the production of bursting pressures in magmas during crystallisation see SCIENCE PROGRESS, January 1923, p. 362.

S. Taber's investigation of the great fault troughs of the Antilles (*Journ. Geol.*, **30**, 1922, pp. 89–114) suggests that the east to west arcs delineating the major relief features of this region are zones of normal faulting developed in late geological times ; and that this faulting has resulted in deep narrow troughs, mostly submerged. These resemble rift valleys with precipitous enclosing scarps, and floors which, instead of being graded like river valleys, rise and fall throughout their lengths. Earthquake phenomena indicate that the displacements are still continuing, but Taber finds no causal connection between the relatively meagre volcanic activity of the Antilles and the foundering of the narrow blocks.

Recent German literature on similar topics includes the following :

L. KOBER, *Der Bau der Erde*, Berlin : Gebrüder Borntraeger, pp. 324.

M. WEBER, "Zum Problem der Grabenbildung," *Zeits. d. D. Geol. Ges. Abh.*, **73**, 1921, pp. 238–89.

H. QUIRING, " Eiszeit und Gebirgsbildung," *Zeits. d. D. Geol. Ges. Monatsber.*, 1921, pp. 281–8.

E. NOWAK, " Sedimentation und Gebirgsbildung," *Naturwiss.*, **44**, 1921, pp. 892–7.

H. QUIRING, " Gebirgsbau der Östkarpathen, Deckenlehre und Vulkanismus," *Zeits. d. D. Geol. Ges. Monatsber.*, 1921, pp. 108–29.

*Stratigraphical and Regional Geology.* The most notable recent work is the following:

HOLTEDAHL, O., "A Tillite-like Conglomerate in the 'Eocambrian' of Southern Norway," *Amer. Journ. Sci.*, **4**, 1922, pp. 165–73.

BUCKING, H., "Beiträge zur Geologie des oberen Brauschtals in den Vogesen," *Neues Jahrb., Beil.-Band.*, **44**, 1920, pp. 100–273.

GROSSE, E., "Grundlinien der Geologie und Petrographie des östlichen Katanga," *Neues Jahrb., Beil.-Band.*, **42**, 1918, pp. 272–419.

WANNER, J., "Beiträge zur Geologie und Geographie von Nordöst-Borneo," *Neues Jahrb., Beil.-Band.*, **45**, 1921, pp. 149–213.

BENSON, W. N., "An Outline of the Geology of New Zealand," *Journ. Geol.*, **30**, 1922, pp. 1–17.

BOSWORTH, T. O., *Geology of the Tertiary and Quaternary Periods in the North-west Part of Peru*, Macmillan & Co., Ltd., London, 1922, pp. 434.

HEALD, K. C., and MATHER, K. F., "Reconnaissance of the Eastern Andes between Cochabamba and Santa Cruz, Bolivia," *Bull. Geol. Soc. Amer.*, **33**, 1922, pp. 553–70.

MATHER, K. F., "Front Ranges of the Andes between Santa Cruz, Bolivia, and Embarcacion, Argentina," *ibid.*, pp. 703–64.

**CRYSTALLOGRAPHY.** By A. SCOTT, M.A., D.Sc.

ALTHOUGH only ten years have elapsed since the publication of the original paper by W. Friedrich, P. Knipping, and M. von Laue (*Sitzber. Akad. München*, 303, 1912) on the investigation of crystal structure by means of X-rays, a large volume of literature on the subject has already accumulated. The results of the work of the last decade are summarised in a series of papers in a recent number of *Die Naturwissenschaften* (Heft 16, 1922). An historical account of the investigation of the interference phenomena of X-rays is given by W. Friedrich (*ibid.*, 363, 1922), and P. Knipping (*ibid.*, 366, 1922) describes the various methods which have been devised in X-ray spectroscopy. The results of the work on the latter subjects are discussed by G. Wentzel (*ibid.*, 369, 1922), who tabulates the absorption limits and the wave lengths of the K-, L-, and M-series for the appropriate chemical elements. The wave length of X-rays is treated by L. Meitner (*ibid.*, 381, 1922), and the bearing of Laue's work on atomic structure by P. Debye (*ibid.*, 385, 1922). The significance of the Laue radiogram from the point of view of crystallography is considered by P. Niggli (*ibid.*, 391, 1922), who summarises the results of the examination of those crystals which have been successfully investigated. E. Schiebold (*ibid.*, 399, 1922) gives a detailed account of the operations involved in the interpretation of the X-ray analysis of a crystal. Bibliographies are appended to several of the papers. Attention may also be drawn to a discussion, by R. Gross (*Fortsch. Min.*, **7**, 65, 1922), of the main methods of investigation, Laue's, Bragg's, and Debye and Scherrer's, and the interpretation of the results.

Numerous investigations of the structure of individual substances have recently been made, and the time seems not far distant when most of the elements and simpler chemical compounds will have been examined. According to A. W. Hull (*Phys. Rev.*, **18**, 88, 1921), the hexagonal elements, titanium, zirconium, cerium, and osmium, each consist of two triangular prismatic lattices with dimensions 2·97Å and 4·72Å, 3·23Å and 5·14Å, 3·65Å and 5·96Å, and 2·71Å and 4·32Å respectively. It is possible, however, that cerium may be more complex. Thorium is composed of a face-centred cube with edge 5·04Å. Lithium is described by J. M. Bijvoet and A. Karssen (*Proc. Acad. Amsterdam*, **23**, 1365, 1922) as belonging to the centred cube type with edge 3·50Å, and beryllium by L. W. McKeehan (*Proc. Nat. Acad. Sci.*, **8**, 270, 1922) as consisting of two interpenetrating hexagonal lattices. The former authors have also examined lithium hydride (*Proc. Acad. Amsterdam*, **25**, 26, 1922). According to the summary by P. Niggli (*loc. cit.*), and a paper by V. M. Goldschmidt (*Zeit. Metallkunde*, **13**, 449, 1921), eighteen elements are known to crystallise in the face-centred cube lattice, six in the centred cube lattice, four in lattices of the diamond type, ten in the hexagonal type, four in rhombohedral lattices, and one in a tetragonal lattice.

An interesting investigation of some of the compounds present in iron and steel has been made by A. Westgren and A. S. Lindh (*Zeit. phys. Chem.*, **98**, 121, 1921). They confirm the results obtained by A. W. Hull (*Phys. Rev.*, **9**, 94, 1917; **10**, 661, 1917) that $\alpha$- and $\beta$-iron have essentially the same structure, both belonging to the centred cube type, while they also show that both V-iron and austenite belong to the face-centred type. Martensite, on the other hand, gives the structure of $\alpha$-iron, and must be largely composed of it, or of $\beta$-iron. In a further paper, A. Westgren and G. Phragmén (*Zeit. phys. Chem.*, **102**, 1, 1922) describe the structure of cementite as orthorhombic, there being four molecules of $Fe_3C$ in the elementary parallelepiped, which has edges of length 4·53Å, 5·11Å, 6·77Å. These results confirm the generally accepted metallurgical opinion that martensite is very largely $\beta$-iron and that austenite is a solid solution of $\gamma$-iron and carbon. The question of the form of the carbon in the latter is interesting. If, as seems probable, the carbon is present as the iron carbide, cementite, then it is feasible to assume that the temperatures at which the austenite solid solution is formed, the lattice of cementite is pseudo-cubic. The structures of some metallic solid solutions have been investigated by E. C. Bain (*Trans. Inst. Min. Met. Eng. Bull.*, 1139, 1922). In the case of the system nickel-chromium, which shows a continuous series of solid solutions, the alloys containing up to 65 per cent. have the nickel structure ; those with above 93 per cent. chromium have the chromium structure, while the intermediate alloys show both. The system copper-manganese is similar, both lattices being detectable in alloys containing from 60 to 90 per cent. manganese. In the systems copper-nickel and copper-gold there is apparently no break, the change being linear. Iridosmine has been shown by G. Aminoff and G. Phragmén (*Zeit. Kryst.*, **56**, 510, 1921) to be composed of a centred hexagonal lattice.

The structures of the oxides of calcium, magnesium, cadmium, and nickel have been examined by W. P. Davey and E. O. Hoffman (*Phys. Rev.*, **15**, 133, 1920), who deduce a face-centred cube arrangement for both the metal and oxygen atoms in each case. E. Schiebold (*Zeit. Kryst.*, **36**, 430, 1921) has also examined magnesia, but in the form of the natural mineral periclase. G. Aminoff (*ibid.*, **56**, 495, 1921) confirms the results of W. L. Bragg (*Phil. Mag.*, **39**, 647, 1919) with reference to zincite. In addition to X-ray analyses of the minerals, an attempt is made by G. Aminoff (*Geol. Fören. Förh. Stockholm*, **41**, 407, 1919 ; *Zeit. Kryst.*, **56**, 506, 1921) to ascribe space groups to brucite and pyrochroite. In another paper by the same author (*Geol. Fören. Förh. Stockholm*, **42**, 211, 1920) the structures of the minerals parisite and synchisite are considered.

The structures of a series of analogous complex compounds, such as ammonium platinichloride, ammonium silicofluoride, etc., have been determined by some American workers. The first-mentioned has been shown by R. W. G. Wyckoff and E. Posnjak (*Journ. Amer. Chem. Soc.*, **43**, 2292, 1921) to be analogous to fluorspar, the ammonium atoms replacing the chlorine and the platinum and fluorine together replacing the calcium. Similarly, ammonium silicofluoride has been investigated by R. M. Bozorth (*ibid.*, **44**, 1066, 1922), who finds that the structure is similar to that of the platinichloride. R. W. G. Wyckoff has examined the series of compounds of the general formula $NiX_2.6NH_3$ (*ibid.*, **44**, 1239, 1922), where X represents the halogen atoms, as well as the compound of similar formula, where X represents $NO_3$ (*ibid.*, **44**, 1260, 1922). The same author (*ibid.*, **44**, 1944, 1922) has shown silver molybdate to be analogous to spinel. Wyckoff (*Amer. Journ. Sci.*, (5), **4**, 188, 1922) has also investigated hexahydrated zinc bromide and has assigned a specific space group to it as well as to acid sodium acetate (*ibid.*, (5), **4**, 193, 1922).

The nitrates of lead, barium, strontium, and calcium have been examined by L. Vegard (*Zeit. Physik.*, **9**, 292, 1922), who finds that the metals are arranged in a face-centred cube with the three oxygens and the nitrogen at the four cube corners surrounded by four atoms of metal so that the symmetry is trigonal. A number of compounds of silver and copper have also been examined by the work of the Geophysical Laboratory. Wyckoff finds silver oxide to be similar to copper oxide (*Amer. Journ. Sci.*, (5), **3**, 184, 1922), but some forms of ammonium chloride (*ibid.*, (5), **3**, 177, 1922 ; (5), **4**, 469, 1922) give a different degree of symmetry from that indicated by the etch figures and external form ; *e.g.*, in one case the X-ray structure indicates tetrahedral symmetry, while the form and etch figures suggest hemihedral symmetry. Wyckoff and Posnjak show that the cuprous haloids have a structure resembling that of zinc sulphide so far as the chloride, bromide, and iodide are concerned. The same authors (*Journ. Wash. Acad. Sci.*, **12**, 248, 1922) have shown that calcium chloride, bromide, and iodide are composed of body-centred lattices (*cf.* W. P. Davey and F. G. Wick, *Phys. Rev.*, **17**, 403, 1921), and R. M. Bozorth (*Journ. Amer. Chem. Soc.*, **44**, 2232, 1922) that cadmium iodide is not hexagonal but trigonal. G. G. Dickenson has examined phosphonium iodide (*ibid.*, **44**, 1489, 1922), and M. L. Huggins, calcium carbonate (*Phys. Rev.*, **19**, 354, 1922). W. H. Bragg (*Proc. Phys. Soc.*, **34**, 918, 1922) discusses the question of the structure of ice and finds that his results agree with those of Dennison (*Phys. Rev.*, **17**, 20, 1921), but not with those of J. John (*Proc. Nat. Acad. Sci.*, **4**, 192, 1918). W. H. Bragg (*Proc. Phys. Soc.*, **34**, 33, 1921) has also examined by the powder method the structure of a number of organic compounds such as naphthaline, $\alpha$-naphthylamine, benzoic acid, acenaphthene, $\beta$-naphthol, while a large number of carbon compounds have been investigated by K. Becker and W. Jancke (*Zeit. phys. Chem.*, **99**, 242, 267, 1921) ; P. Niggli (*Zeit. Kryst.*, **57**, 253, 1922) has assigned specific space-groups to cuprite, tenorite, and silver oxide, while F. Rinne and his co-workers have published a series of papers in *Abhand. Sachs. Akad. Wiss.* (*Abs. in Chem. Cent.*, **1**, 626, 1921) assigning, on the basis of the X-ray structure and the physical properties of the crystals, specific space-groups to such minerals as olivine, tourmaline, cobalt-glance, and carborundum. In each case the dimensions of the lattice have been determined as well as the number of atoms in the elementary parallelepiped. There are four molecules of the orthosilicate in the case of olivine in the unit structure, and four of CoAsS in the unit of the cobalt-glance. The three forms of carborundum, which on the basis of the etch-figures are supposed to differ, are shown from the X-ray examination to be the same since only type of lattice, prismatic hexagonal, is present.

Although it may not be possible at present to elucidate completely the structure of complex silicates by means of X-ray analyses, the method has been successfully applied in connection with certain problems relating to the felspars, especially with reference to the relations of orthoclase and albite to perthite. Although the equilibrium relationships of the former minerals are not completely known, thermal analysis has indicated the possibility of the breakdown of a solid solution at some temperature below the solidus curve, and it is believed that perthite is the resultant product. In order to test this view, S. Kôzu and Y. Endô (*Sci. Rep. Tôhoku Univ.*, (3), **1**, 1, 1921) have made X-ray analyses of adularia and moonstone, both in the condition as found in nature and after heat treatment to various temperatures and quenching. The structure of natural adularia indicates a simple solid solution in which corresponding atoms replace each other without interference with the structure (cf. L. Vegard and H. Schjelderup, *Zeit. phys. Chem.*, **18**, 93, 1917). In moonstone, however, the Laue pattern shows a duplication of many of the spots, indicating inhomogeneity of the structure, there being present two types of spacing with monoclinic symmetry. The heated samples of adularia show practically the same structure as the untreated up to the highest temperature tried, 1,060° C. In the heated samples of moonstone, the spots in the " doublets " tend to approach each other as the temperature of heating rises. Treatment to a temperature just above 1,060° C. results in the coalescence of the constituent spots of the doublets, indicating that only one type of solution is present. At about 1,190° C. the crystalline structure disappears, as the result of the material melting.

From a similar examination of schiller spar, the authors conclude that schillerisation is due to the interference of light waves passing through the two types of lattice. In another paper (*Sci. Rep. Tôhoku Univ.*, (3), **1**, 19, 1921) S. Kôzu and M. Sizuki give chemical and optical details for the Korean schillerised felspar, while the composition and fusion phenomena of sanidine from the Eifel are discussed by S. Kôzu and K. Seto (*ibid.*, (3), **1**, 25, 1921).

By means of X-ray examination E. W. Washburn and L. Navius (*Journ. Amer. Cer. Soc.*, **5**, 565, 1922) have examined the products of calcination of chalcedony and flint. The nature of both of these minerals has been in some doubt, although Fenner suggested that the former was composed essentially of quartz. This is now verified by the X-ray examination, and it is shown that both minerals are mainly composed of a very finely divided form of quartz. The effect of calcination is likewise shown to be transformation into cristobalite. Attention might also be called to the use of similar methods in connection with the investigation of such metallic oxides as those of iron, aluminium, cobalt, nickel, etc., when prepared from the hydrate (J. A. Hedvall, *Zeit. anorg. Chem.*, **120**, 87, 1922).

H. C. Burgen, by the use of the same methods, has shown that both tungstic $WO_3$ and the hydrate $H_2WO_4$ are crystalline and have different structures, while similar results are obtained for the hydrates $H_4WO_5$ and $H_2MoO_4$ (*ibid.*, **121**, 240, 1922). By means of Debye and Scherrer's method, J. W. Mellor and W. H. Bragg (*Eng.*, **114**, 456, 1922) have confirmed the view previously advanced by the former, that kaolinite breaks up, on heating to 500° C., into an amorphous mixture, the crystalline structures being well defined in material heated to temperatures below 500° C., but non-existent in those heated above that temperature.

**BOTANY.** By E. J. Salisbury, D.Sc., F.L.S., University College, London.

*Taxonomy.*—A new species of *Statice* (*S. anfracta*) from the Dalmatian coast is described by Salmon in the *Journal of Botany* for December. It is most closely allied to *S. remotisspicula* of Lacaita from which it differs in the numerous sterile branches, more zig-zag scape and the form of the bracts.

In the same journal Miss Lyle describes a new genus of marine algæ, closely allied to *Antithamnion*, termed *Antithamnionella*. In the possession of two kinds of branches, alternate and verticillate, the latter genus agrees with the former, but approaches *Callithamnion* and *Spermothamnion* in the triangular division of the tetraspores. Three species are recognised of which *A. sarnensis* is new, whilst *A. ternifolium* and *A. verticillatum* were doubtfully referred by De Toni to *Antithamnion*. The distribution of the three species is interesting. All three are epiphytes and have been found respectively in Guernsey, the Cape of Good Hope, and Cape Horn.

The Report of the Botanical Society and Exchange Club, vol. vi, Part III, contains a paper on the British Centaureas of the *Nigra* group by C. E. Britton. the following are recognised: *C. obscura* Jord., in which he distinguishes four forms of the type, var. *subnemoralis* with one form; *Centaurea surrejana* sp. nov.; *C. Drucei* sp. nov. with five forms; *C. nemoralis* with var. *diversifolia* and four forms, and *V. subintegra* and three forms, *V. minima* with a radiate form, *V. microptilon*, *V. Debeauxii*. In the same journal Dymes describes the seeds of the British Dactylorchids, and in a supplement Druce gives a list of Shetland plants numbering 505. This number is exclusive of 70 species previously recorded, but probably mostly errors of identification. Of the total, 446 are regarded as native.

*Ecology and Distribution.*—Osmaston, in the *Journal of Ecology* for November, describes the vegetation of the Garhwal

Himalaya. In this region most of the area below an altitude of 8,000 ft. is cultivated provided the slope is not too great. Most of the uncultivated areas present a gradient of about 35°, and the climatic conditions, especially rainfall, are apparently the predominant factors in determining the character of the vegetation. Five climax formations are recognised:

I. The Caragana-Lonicera-Artemisia Formation. This is found in the region with an average precipitation of under ten inches, most of which falls as snow during the resting season. Trees, grasses, and shallow-rooted plants are absent and the deciduous vegetation is usually very xerophytic and characterised by the presence of *Artemisia maritima, A. sacrorum, Caragana Gerardiana, C. pygmæa, and Lonicera spp.* Where there is a good supply of subsoil water, however, this arid region produces a vegetation dominated by *Myricaria germanica, Salix hastata* and *S. sclerophylla.*

II. The Betula-Rhododendron Formation, which occurs between altitudes of 9,000 and 13,500 ft., where the precipitation is from ten to eighty inches per annum, of which from one-quarter to three-quarters falls during the period of vegetative activity. The conditions are appreciably more humid than in the arid zone, and the vegetation is either shrubby, consisting of species of *Rhododendron* and *Lonicera,* or low trees such as *Betula utilis* and *Abies Webbiana* may preponderate.

III. The Pinus-Cedrus Formation occurs in the drier regions between 6,500 and 12,000 ft., where the annual precipitation is from ten to forty inches and fairly evenly distributed. The vegetation is considerably affected by aspect, and the prevailing trees are either conifers, *e.g. Cedrus deodara, Cupressus torulosa,* and *Pinus excelsa,* or hardwoods such as *Æsculus indica, Acer cæsium, Corylus colurna.*

IV. The Shorea-Anogeissus-Pinus Formation. This occupies the moist valleys below 6,500 ft. with a similar precipitation to V, but drier and characterised by the presence of *Pinus longifolia, Anogeissus latifolia,* and other trees.

V. The Quercus-Abies Formation is found between 5,000 and 11,500 ft., with a precipitation of from fifty to eighty inches. This is a mesophytic type of vegetation, characterised by the presence of evergreen oaks (*Quercus semecarpifolia, Q. incana*) *Abies Pindrow,* and deciduous types. In this moister zone of vegetation a marked edaphic effect is found where limestone soil occurs, the drier conditions resulting in the replacement of the Quercus-Abies formation by the more xerophytic Pinus-Cedrus formation.

An important contribution to the study of plant distribution in Europe has been made by Sterner (*Geografiska Annaler,* pp. 221–444, 1922), in which he treats of the continental element in the Flora of South Sweden. The author divides the European continental species into four classes, viz.: I. Meridional: species which occur mainly in the steppe regions of East Europe. II. Meridio-Boreal: species found commonly in the Steppe and forest regions of central and northern Russia. III. Boreal: species mainly found in the forest region of central and northern Russia. IV. Siberian species. In each of these classes the distribution type outside eastern Europe is subdivided under a number of headings. Thus *Ranunculus illyricus* is a Meridional species with a pontic distribution; *Veronica spicata* is a Meridio-Boreal species with a pontic and sarmatian distribution whilst *Potentilla fruticosa* is a Siberian type. Most of the continental (E. European) species show a type of distribution which is central European in character with a western limit which tends to form a boundary-line from north-east Russia in a south-westerly direction to the south-east of France, sometimes with a marked extension into Scandinavia. Towards the south-westerly limit marked discontinuity of distribution is a feature of some species, notably *Adonis vernalis*. As a class the continental species are regarded as characteristic of soils rich in electrolytes, with a high porosity and power of heat absorption. They, and above all the steppe species, often occur, outside definitely continental climatic conditions, as calcicoles; a fact which is attributed to a high tolerance for lime and conditions of low humidity unfavourable to other species. Continental species are also mostly heliophiles. The continental species in the south Swedish Flora number about 115, or approximately 12 per cent. of the really native species (casuals, aliens, species of cultivated ground being omitted). The corresponding percentage of continental species in the native flora of other areas is 1·2 per cent. for south-east England, 4·9 for northern France, 18 per cent. for western Prussia, 26·6 per cent. for Moscow, 5 per cent. in Norway, and 8 per cent. in Denmark. In south Sweden the continental element is met with chiefly in the dry meadows, the grass heaths, and on the gravelly ridges of the south Swedish highland. During the Boreal and Sub-boreal periods of early post-glacial times it is suggested that the steppe species probably had a much wider distribution, but under the more oceanic climate of the existing period they are almost restricted to the calcareous or sandy soils, arable land, or the slopes of the gravelly ridges where the dry conditions and high insolation which favour their occurrence obtain. The study of the continental element suggests that the south-eastern part of Sweden belongs to the floral region of Sarmatia (= East Baltic wood region of Drude), whilst the south-western part belongs to the Sub-atlantis region (north German plain west of Sarmatia).

Burgess (*Soil Science*, Sept. 1922) describes a new type of press for directly obtaining the true soil solution. Comparisons of the composition of solutions obtained by this means with the ordinary 1 : 5 pure water extract show a fairly close correspondence as regards Calcium, Magnesium, and Nitrate ions, but the water extract yielded 1·7 times as much sulphate and 3·5 times as much Potassium ions. The discrepancy with respect to the Phosphate ion was even greater, being about 30 times more than in the real soil solution.

Larsen, in *Ecology* for October, gives some interesting data obtained by the U.S. Forest Service respecting the effect of forests on meteorological data from three stations, one in the dense forest, a second in a partially cleared area (one-third forest), and a third in an open clearing. The range and extremes of temperature diminished with the increase of cover, as also the average daily evaporation and soil temperature. The relative humidity increased with the increase of cover.

**PLANT PHYSIOLOGY.** By R. C. Knight, D.Sc., Imperial College of Science and Technology (Plant Physiology Committee).

*Physiological Action of Fungicides.*—Shortly after the introduction of Bordeaux mixture as a fungicide, it was observed that its application resulted in changes in the sprayed plants which could not be attributed merely to the fungicidal action. Much isolated work on this question was reported from European sources from about 1890 onwards, and it is only more recently that the matter has been seriously investigated. It is perhaps to be expected that the distribution over the plant of compounds of copper will not be without effect upon the plant itself, apart from the toxic action on fungi, and of course extreme cases of "Bordeaux injury" are of fairly common occurrence. Grubb (*Journ. Pomology*, 1921, **2**), in the course of tests of fungicides on apples, made observations on spray injury and devotes a section of his paper to its consideration. Bordeaux injury is manifested by the early fall of the leaf, generally within a few weeks of spraying, and also by the russeting of the fruit. This injury appears to be decreased almost to zero, without loss of fungicidal action, by the use of excess of lime. Apart, however, from the extreme cases of injury due to the toxicity of the strength of spray applied, there are other physiological effects of the spray which may have a very important influence on the constitution of the plant and its crop. Grubb observes that in general the application of a spray increases the size of the individual fruits apart from any effect on the amount of the total crop. No explanation is offered as to whether this is merely a negative influence brought about by the reduction of fungal infection, or whether it is a direct effect upon the tree itself.

The general physiological result of Bordeaux spray is expressed in the phrase "greater longevity," and frequent cases of this have been observed and recorded. References to the earlier literature will be found in the majority of the papers quoted below. Clinton in 1909 was the first to refer this increased longevity to the water relations of the plant. His explanation was that the film of sediment from the spray clogged stomata and hydathodes and thereby reduced water loss. His reasons were (1) the absence of "tip burn" in dry seasons from sprayed plants, and (2) the observation that sprays with little sediment did not prolong the life of the plant. Other workers at the time subscribed to this idea, but careful experimental work almost immediately afterwards showed that exactly the reverse was in fact the case, namely, transpiration was actually increased by spraying. Duggar and Cooley in more recent years have attacked the problem with the better methods now available, and have published a series of papers. In the first work (*Ann. Mo. Bot. Gard.*, 1914, **1**, 1–22) they used *Ricinus* leaves in potometers and tomato plants in pots, and found considerably higher transpiration rates in sprayed than in unsprayed *Ricinus* leaves. The same result was obtained with the potted tomatoes, and in this case, in addition, data were collected showing that various other surface films besides Bordeaux may produce in some degree the same effect. Among the substances used to produce the film were $Ca(OH)_2$, $Al(OH)_3$, clay, charcoal, $CaCO_3$ and lime-sulphur mixture, but the results obtained, although showing differences from the controls, hardly warrant anything but a tentative conclusion. The same remark applies to the water requirement figures for tomato, which vary from 13·1 (sprayed with charcoal) to 11·8 [$Ca(OH)_2$] with the control giving 12·1. The same authors report a trial with potted potatoes (*Ann. Mo. Bot. Gard.*, 1914, **1**, 351–6) which gave quite similar results, the transpiration from plants sprayed with weak Bordeaux being 50 per cent. greater than from the controls. Martin (*Journ. Agr. Res.*, 1916, **7**, 529–48) repeated the experiments of Duggar and Cooley under different conditions in a different locality. Using a variety of species at different times, Martin found that the average transpiration increase due to Bordeaux spraying, for all plants used, was about 100 per cent., with the extremes of 37 per cent. for *Datura metaloides* and 272 per cent. for *Hibiscus cardinalis*. He also agreed with the earlier workers that the extent of the increase varied with the nature of the film. A further observation was that the influence was greater on detached leaves than on potted plants. The accelerating influence was found to be greatest immediately after the drying of the spray. The evidence for an increased transpiration rate following Bordeaux spraying was completed by Shive and Martin (*Plant World*, 1917, **20**, 67–86), who used the hygrometric paper method to test tomatoes growing in the open, and were able to confirm the results obtained by Duggar and Cooley and by Martin. In addition Shive and Martin observed that the accelerating influence of the spray was effective whether climatic conditions were such as tended to produce high or low transpiration rates. Further analysis of the transpiration problem was attempted by Duggar and Bonns (*Ann. Mo. Bot. Gard.*, 1918, **5**, 153–76), who used potted potatoes, tomatoes, marguerites, tobacco and *Cyperus*, and took special precautions to ensure that all plants in a series were subject to identical environment. Increased transpiration rates due to Bordeaux spraying were again demonstrated in mesophytes, and, moreover, it was found that practically the whole of the observed increase took place during the night intervals. In this fact the authors consider they have found the clue to the mechanism of the acceleration. At night, in a greenhouse with the usual temperature and humidity fluctuations, many plants are in a state of guttation or incipient guttation, and it is supposed that a film of dried Bordeaux would under these conditions act as a bibulous layer, spreading the guttation water and thereby causing a greater loss. During the day, in the absence of guttation, the stomata function normally and the surface film no longer asserts its bibulous nature. No accelerating effect was found in the case of *Cyperus*, and the authors believe that the minute size of the stomata and intercellular spaces in this plant results in the clogging of the pores with a consequent occasional transpiration decrease. In the case of excised leaves it is not certain, of course, that a state of guttation is established as frequently as in growing plants, even if such a state exists at all, so that, pending further work, the explanation of results obtained with detached leaves is still in abeyance.

The work on transpiration has served clearly to show that the Bordeaux influence is very much subject to climatic and environmental conditions generally, and also to the nature of the plant treated.

With regard to the influence of Bordeaux spray on other physiological functions of the plant, work has been in progress for nearly thirty years, the main results of which need be summarised only very briefly here. In general, spraying has been found to deepen the green colour of the leaf and to postpone leaf fall, at the same time causing the leaf to become abnormally thick. The increased depth of colour was ascribed by Rumm (1893) to an increase in the number of chloroplasts. Increase of chlorophyll content has also been observed by Frank and Krüger (1894), Zucker (1896), Bayer (1902), and Schrauder (1904). Many experiments measuring the influence of Bordeaux on yield have been recorded. Ewert (1905) attempted to distinguish between the influence in full sunlight and in shade, but it is evident from his experiments that there were too many factors uncontrolled to permit conclusions to be safely drawn from his results. In 1912 a further paper recorded more satisfactory results, and it was found that strengths of Bordeaux above 2 per cent. reduced the yield of potatoes and radishes. The yield of some varieties of beans was improved by Bordeaux, and other results obtained include increase of sugar content of currants and gooseberries. There is a general tendency throughout to ascribe the effects to the shading provided by the spray. A full summary of the earlier work is given by Butler as a preface to his paper on the subject (*New Hampshire Agric. Exp. Sta.*, 1922, Tech. Bull. 21). Butler found, using radish, tomato and bean, that a reduced yield generally resulted from Bordeaux and milk of lime sprays, and that the transpiration per gram dry matter was increased by the spray. He also concluded that the action of the Bordeaux was not due to the copper, but was controlled by the copper-lime ratio, in other words by the excess lime. Observations of leaf colour failed to demonstrate any constant effect. Darker green plants were certainly more frequent in the sprayed series, but little more could be said. The results in general were very variable, and in some experiments the author is reduced to expressing them as "percentage of sprayed plants showing increase." For example, transpiration per gram dry matter was increased by spraying in 95 per cent. of the tomato plants, 69 per cent. radish, and 64 per cent. bean. Cultures in sand supplied with varying nutrient solutions showed that spraying produced the same effect in all cases. Again, in these conditions sprayed plants transpired more water. In general the higher the water content of the soil the greater was the depressing effect of spray on dry-matter production. Photometer experiments were carried out to determine the actual proportion of light stopped by Bordeaux of various strengths, but the figures given can of course have only a relative significance owing to the inevitable wide differences of distribution which occur in practice. However, it is of course realised that the spray must cast a shadow, and to this may possibly be attributed the delay in ripening which has been definitely reported by Edgerton (*Louis. Agr. Exp. Sta. Bull.*, **164**, 1918) and Massey (*New Jersey Agr. Exp. Stat. Report*, **40**, 1920, 541), and which is doubtless a factor concerned in the delayed leaf fall. Butler observed that the heliotropic response of sprayed bean leaves was slower than that of normal leaves, and ascribes this delay to the shading effect. No qualitative differences could be found between the light transmitted by Bordeaux mixtures of various copper-lime ratios. Butler considers that the increased transpiration rates following spraying (which, in common with Duggar and Bonns, he found to occur at night) are to be attributed to the reduction of heat radiation by the film of spray and the consequent higher temperature of sprayed leaves. In short, all the direct physiological influences of Bordeaux mixtures on the plant may be attributed to the shading action of the film, diminishing light in the day, and loss of heat at night. This conclusion agrees with Ewert's and also in part with Clinton's observations that maximum effect was obtained with sprays giving a heavy sediment. Throughout the work there is no attempt to ascribe any of the direct effects of Bordeaux to any chemical action of the copper present, which is, after all, the most natural constituent to suspect. In fact it has been shown by Porchet that copper can never be detected in plants sprayed with Bordeaux, whilst it is easy to demonstrate copper in plants if copper salts are supplied to the roots. Copper, therefore, does not penetrate the leaves, and the general conclusion of all investigators is that the physiological influence of Bordeaux mixture on plants is capable of a physical interpretation.

### References to Earlier Work on the Subject

Aderhold, R., "Über die Wirkungsweise der sogenannten Bordeauxbrühe (Kupferkalkbrühe)," *Centralbl. Bakt.*, 1899, **5**, 217–20, 254–71.

Bain, S. M., "The Action of Copper on Leaves," *Tenn. Agr. Exp. Sta. Bull.*, 1902, **5**, No. 15.

Bayer, L., "Beiträge zur Pflanzenphysiologischen Bedeutung des Kupfers in der Bordeaux-brühe," Königsberg, 1902.

Chuard, E., et Porchet, F., "Influence des composés cupriques sur les phénomènes de maturation," *Bull. Soc. Vand. Sci. Nat.*, **36**, 71.

Clinton, G. P., "Spraying Potatoes in Dry Seasons," *Conn. Agr. Exp. Sta. Rpt.*, 1909–10, 739–52.

Ewert, R., "Der wechselseitige Einfluss des lichtes und der Kupferkalkbrühe auf den Stoffwechsel den Pflanze," *Landw. Jahrb.*, 1905, **24**, 233–310.

Ewert, R., "Weitere Studien über die physiologische und fungicide Wirkung der Kupferbrühen bei Krautigen Gewächsen und der Johannisbeere," *Z. Pflanzenkr.*, 1912, **22**, 257–85.

Lutman, "Some Studies on Bordeaux Mixture," *Vermont. Agr. Exp. Sta. Bull.*, **196**, 1916.

Porchet, P., "Action des sels de cuivre sur les végétaux," *Bull. Soc. Vand. Sci. Nat.*, 1903, **39**, 461–552.

Ruhland, W., "Zur Kenntniss der Wirkung des unlöslichen basischen

Kupfers auf Pflanzen mit Rucksicht auf die sogenannte Bordeaux-brühe," *Arb. Biol. Anst.*, 1905, **4**, 157–200.
SCHRAUDER, R., " Über die physiologische Wirkung der Kupferkalkbrühe," *Landw. Jahrb.*, 1904, **33**, 517–84.
ZUCKER, A., " Beiträge zur direkten Beeinflussung *der* Pflanzen durch die Kupfer-vitriol-Kalkbrühe." Thesis, Stuttgart, 1896.

**ZOOLOGY.** By REGINALD JAMES LUDFORD, Ph.D., B.Sc., University College, London.

*Protozoology.*—R. L. Phillips describes in the *Jour. Expt. Zool.*, vol. xxxvi, No. 2, Aug. 1922, a series of experiments on the continued growth of *Paramœcium aurelia* in pure cultures and mixtures of bacteria isolated from hay infusions and other infusions used for growing Paramœcium. Mixtures of bacteria appear to be the most satisfactory food. Of all the artificial mixtures tested, only two furnished adequate food over a long period of time. " When Paramœcia are fed with known mixtures of bacteria, it is found that minor fluctuations in division rate occur which are independent of endomixis, and, like it, do not seem to be greatly influenced by environment. The evidence gathered tends to favour constancy of food rather than frequent change. The influence of ordinary media is practically without effect. Paramœcium is unable to utilise food substances dissolved in such media."

*Cytology.*—T. S. P. Strangeways has made a series of observations on cells of the embryonic choroid of the chick during growth *in vitro* (" Observations on the Changes seen in Living Cells during Growth and Division," *Proc. R.S.*, vol. xciv, No. B, 658). During the " resting " stage of the cells, nucleoli were seen to undergo amœboid movements, and division and subsequent fusion of the parts of this nuclear organ occurred fairly frequently. Complete cell division was found to take from 23 to 65 minutes, and the interval between two successive divisions was between 11 to 12 hours. The writer states that the impression given by many observations is that the formation of the nucleolus during the telophase of cell division, is intimately associated with the disappearance of the chromosomes, " but further observations and study are required on this point."

The behaviour of the Golgi Apparatus in the cells of the mammary gland of the rat and guinea-pig has been investigated by C. Da Fano (" On Golgi's Internal Apparatus in Different Physiological Conditions of the Mammary Gland," *Jour. of Phys.*, vol. lvi, No. 6, Oct. 1922). It was found that in the virginal condition of the animals, the apparatus consisted of one or more small reticular portions, situated close to the nucleus on the side facing the glandular lamina. During pregnancy the apparatus enlarges and tends to surround the nucleus. From the time when the young are born, and throughout lactation, the apparatus remains hypertrophic, " in part fragmented and shifted and stretched in various directions. The hypertrophy and partial fragmentation are very likely connected with the activity of the cells ; the shifting and stretching appear chiefly due to the increased intracellular pressure. These facts are against the identification of the apparatus with a fixed system of intra-protoplasmic canaliculi." During the period of involution after lactation when the epithelial cells undergo considerable changes, the apparatus is broken up into a number of pieces of various shapes. Most of these cells are eliminated with their deformed apparatus. Some, however, remain and form the permanent epithelium of the " resting " gland, and Da Fano suggests that the apparatus of such cells is rebuilt from the " fragmented and perhaps fluid materials out of which the old one was formed."

Other important papers are :

Berg, W., " Ueber funktionelle Leberzellstrukturen II, " *Archiv für mikroskop. Anat.*, vol. xcvi, No. 1, 1922.

Bonner, G., " Double Sex-linked Lethals in *Drosophila melanogaster*," *Acta Zoologica*, 1, 1922.

Bowen, R. H., " On the Idiosome, Golgi Apparatus, and Acrosome in the Male Germ Cells," *Anat. Rec.*, vol. xxiv, No. 3, Oct. 1922—a survey and synthesis of recent researches.

Gutherz, S., " Das Heterochromosomen-Problem bei den Vertebraten," Part II—" Untersuchung der Spermiogenese der weissen Maus," *Archiv für mikroskop. Anat.*, vol. xcvi, No. 1, 1922.

Voss, H., " Der mikrochemische Nachweis oxydativer Fermente in den Spermien des Menschen," *Archiv. für mikroskop. Anat.*, vol. xcvi, No. 1, 1922.

*Histology.*—The second part of O. Van der Stricht's " Étude de la Rétine par l'ancienne méthode d'impregnation au nitrate d'argent " (*Archiv de Biol.*, vol. xxxii, No. 3) is devoted to an account of the application of this method to the study of the radial fibres of Müller and the external limiting membrane of the retina, and emphasises the value of this method in the investigation of these structures.

A study of the lymph nodes of the common wild rat has shown that there are two structural types. Either the nodular part of the gland surrounds the sinusoidal portion, except at the hilus, or the nodular and sinusoidal portions are lodged at opposite ends of the node. Accessory nodes, which are the result of some special stimulus, are always of the former type (" Studies on Lymph Nodes "—(1) Structure : Introductory paper, by T. T. Job. *Am. Jour. of Anat.*, vol. xxxi, No. 2, Nov. 1922).

C. C. Macklin has dissected from the fresh trachea and larger bronchi of the mammalian lung, the entire elastic membrane of the branchial tree. Of this membrane, he states that " it is by far the most efficient part of the recoil mechanism of the branchial tree, and is a very important, if not the most important, part of the recoil mechanism of the entire lung." (" A Note on the Elastic Membrane of the Bronchial Tree of Mammals, with an Interpretation of its Functional Significance," *Anat. Rec.*, vol. xxiv, No. 3, Oct. 1922).

J. Thornton Carter has investigated the microscopic structure of the enamel of the teeth of the Primates and other Mammals (" On the Structure of the Enamel in the Primates and some other Mammals," *Proc. Zool. Soc. Lond.*, Part III, 1922). He finds that the enamel pattern affords a useful test of affinity if taken in conjunction with the character of the tube-penetration, and enables one to discriminate between Multituberculates, Marsupials, and Placentals.

A joint paper by P. N. Johnstone, F. H. Wakefield, and H. M. Currey is devoted to a comparison of the vascularity of the Purkinje fibres and of the heart muscle of the calf (" On the Comparative Vascularity of Heart Muscle and of the Purkinje Fibers," *Anat. Rec.*, vol. xxiv, No. 2, Sept. 1922). The vascular supply of the Purkinje fibres is very scanty in comparison with the heart muscle. The writers suggest that these fibres do not represent tissue specialised for the same type of contractility as heart muscle.

Other papers include :

AGDUHR, E., " Einige wahrscheinlich bisher unbekannte, teils im Ependym gelegene, teils in die Fossa rhomboidea hineinragende Nervenendigungen," *Acta Zoologica*, No. 1, 1922.

DRAHN, F., " Ueber den histologischen Bau der Gleitsehne des Musc. biceps brachii beim Pferd," *Archiv für mikroskop. Anat.*, vol. xcvi, No. 1, 1922.

*Embryology.*—The development of the sex organs of the mollusc *Limax maximus* L. has been worked out by H. Hoffmann (" Über die Entwicklung der Geschlechtsorgane bei *Limax maximus* L.," *Zeit. für Wiss. Zool.*, vol. cxc, No. 4, 1922). All the genital organs arise from an ingrowth of the ectoderm at the posterior end of the mantle cavity. The anlage develops first, when the common anlage of the heart, pericardium, and kidney has separated into its single constituent parts. No connection exists between the anlage of the sexual organs and the common anlage of the heart, pericardium, and kidney. The hermaphrodite gland develops the earliest, out of an enlargement of the proximal ends of the primary genital ducts. The proximal half of this duct remains thin and represents the hermaphrodite duct ; the distal half, however, enlarges and becomes the sperm-oviduct which distally is separated into two distinct ducts.

G. S. Sansom contributes to the *Journal of Anatomy* (vol. lvi, Parts III and IV) a paper on the "Early Development and Placentation in *Arvicola* (*Microtus*) *amphibius*, with Special Reference to the Origin of Placental Giant Cells." The development of *Microtus amphibius* is of the excentric type, agreeing in general outlines with that of the mouse and rat. Phagocytic giant cells arise from endothelial cells of the maternal capillaries which surround the implantation cavity at an early stage. All the placental giant cells have the same maternal endothelial origin. The penetration of the ectoplacental trophoblast is assisted by the giant cells which destroy the decidual tissue in its line of advance.

"The Relative Distribution of Clasmatocytes in the Various Organs of the Seven-day-chick Embryo" is the subject of a paper by C. S. Beck (*Anat. Rec.*, vol. xxiv, No. 2, Sept. 1922). Clasmatocytes occur in considerable numbers in all those structures of the embryo which contain loose reticular mesenchyme, their numbers apparently varying according to the amount of that tissue present. "The brain, excluding the optic lobes and retina, is the only structure supposedly containing no loose reticular mesenchyme in which clasmatocytes are found."

T. Pehrson contributes "Some Points in the Cranial Development of Teleostomian Fishes" to *Acta Zoologica*, No. 1, 1922. This paper deals with the development of the primordial cranium of *Amia calva* and the development of the bones related to the sensory canals. In discussing the general results of this work, the writer points out that certain features such as the presence of independent supra-orbital cartilages and the development of a frontal foramen epiphyseos, point to primitive relations in Amia.

Of importance, also, are the following papers:

Janosik, J., "Explication des diverses formes et de la position des reins," *Archiv de Biol.*, vol. xxxii, No. 3, 1922.

Janosik, J., "Le développement de la rate et ses relations avec la 'Bursa Omentalis,'" *Archiv de Biol.*, vol. xxxii, No. 3, 1922.

Salazar, A. L., "Sur la forme de dégénérescence des follicules anovulaires de Regnaud et d'autres reliquats provenant des cordons ovigènes de l'ovaire de la lapine," *Anat. Rec.*, vol. xxiv, No. 2, Sept. 1922.

*Invertebrate Morphology* (excluding Entomology).—In a paper "On some Scottish Oligochæta, with a Note on Encystment in a Common Freshwater Oligochæte, *Lumbriculus variegatus* (Müll) (*Trans. Roy. Soc. Edin.*, vol. liii, Part II, No. 14), J. Stephenson describes two new forms and records the presence of certain species which have not hitherto been found in the British Isles. Of the new species, *Vejdovskyella comata* (Vejd.), var. *scotica* was taken from a pond on a hill above Ascog, Bute, while the other, *Tubifex* (*Peloscolex*) *insularis*, was found between tide-marks in the same district. In recording the presence of *Chætogaster langi*, Bretscher, in a pond in Bute, Stephenson points out that it is the same species as was found by him in ponds in Northern India.

A revision of the Isopod genus Ligia (Fabricus) has been made by H. G. Jackson (*Proc. Zool. Soc. Lond.*, Part III, Sept. 1922). The writer has drawn up a key to the genus, and described the morphology and distribution of seventeen species. Five of the species of earlier writers have been omitted owing to insufficiency of description or doubtful validity.

E. Schreiber has contributed to the *Zool. Jahr.*, Bd. 43, Heft 4, a paper on the structure, development, and habits of some freshwater Ostracods. The mode of life of eight species is given and the development of *Cyprinotus incongruens* is dealt with in detail, the characteristics of its eight larval stages being described and figured ("Beiträge zur Kenntnis der Morphologie, Entwicklung und Lebensweise der Süsswasser-Ostracoden").

Other papers of interest include:

HERFS, A., "Über einige drüsig differenzierte Epithelien bei Schnecken," *Zool. Jahr.*, vol. xliii, No. 4, 1922.

HERFS, A., "Studien an den Hautdrüsen der Land- und Süsswassergastropoden," *Archiv für mikroskop. Anat.*, vol. xcvi, No. 1, 1922.

MERTON, H., "Ergebnisse einer zoologischen Forschungsreise in Brasilien 1913–1914 von E. Bresslau, Neue Beiträge zur Anatomie von Temnocephala," *Zool. Jahr.*, vol. xliii, No. 4, 1922.

*Vertebrate Morphology.*—E. P. Allis, junr., gives a very full account of the cranial anatomy of Polypterus in the *Jour. of Anat.*, vol. lvi, Parts III and IV ("The Cranial Anatomy of Polypterus, with Special Reference to *Polypterus bichir*"). The cranial structures described include the neurocranium, nasal sac and apertures, and latero-sensory canals, also the special osteology, myology, angiology, and neurology of the cranial regions.

A paper by G. Söderberg on "Contributions to the Fore-brain Morphology in Amphibians" (*Acta Zoologica*, 1, 1922) contains descriptions of the telencephalon in frog and Triton embryos, and in the adult stages of these animals. Another important paper on the cranial anatomy of Amphibians is that of W. H. van Seters on "Le développement du chondocrâne d'Alytes obstetricans avant la métamorphose" (*Archiv de Biol.*, vol. xxxii, No. 3).

As the result of the study of the development of the vertebræ of the urodele Necturus, D. L. Gamble concludes that the change in attachment of the rib, from the centrum to the neural arch in urodeles, is not the complicated process that Goeppert described. The capitular head of the rib does not remain attached to the basal stump or vestige of it, but loses its connection with the parapophysis and joins with the rib-bearer. This change in rib attachment is correlated with the dorsal shifting of the horizontal septum ("The Morphology of the Ribs and Transverse Processes in *Necturus maculatus*," *Jour. of Morph.*, vol. xxxvi, No. 4, Sept. 1922).

In "Notes on the Anatomy of *Cacopus systoma*, an Indian Toad of the Family Engystomatidæ" (*Proc. Zool. Soc. Lond.*, Part III, Sept. 1922), D. W. Devanesen points out that most of its special peculiarities are attributable to the nature of its food, which consists almost entirely of termites, and its habit of passing the greater part of its life underground and seeking water only for breeding purposes. A new structure was found in the pharynx of this toad, which the writer has named the "pharyngeal organ."

The morphology of the carapace of the tortoise *Testudo loveridgii* Blgr. is described by J. B. Procter in the *Proc. Zool. Soc. Lond.* (Part III, Sept. 1922). This tortoise is of special interest in that it has an excessively depressed, soft-shelled carapace, and is able to inflate itself to a certain degree. It possesses a bony carapace and plastron, but they are extensively fenestrated, incomplete, and similar in essentials to the juvenile stages of other species. Several points of importance in the study of the morphogeny of the chelonian carapace have arisen in this study. The writer finds that fenestration in this and other species is caused by arrested development, and not, as has been generally supposed, by absorption with age. Evidence is also adduced to show that the development of the bony plates in *T. loveridgii* and the young of other species points to the neurals and costals being of dermal origin ("A Study of the Remarkable Tortoise *Testudo loveridgii* Blgr., and the Morphogeny of the Chelonian Carapace").

A paper by C. Forster Cooper on "Miocene Proboscidia from Baluchistan" (*Proc. Zool. Soc. Lond.*, Part III, 1922) contains a description of some Proboscidian remains obtained during two expeditions to the Lower Miocene deposits of Dera Bugti, Baluchistan. Special interest is attached to these remains as they throw some further light on the earliest known Indian elephants. *Bunolophodon angustidens* and a small *Dinotherium* were the forms found. The former is a small type more primitive than the French ones from Sansan. Lydekker's subspecific name var. *palæindica* may be retained for the present until intermediate forms are found to occur. The *Dinotherium* does not differ from the smaller European forms nor from *D. nobleyi* of Africa.

In a paper "On Truncated Umbilical Arteries in some Indian Mammals" (*Jour. of Anat.*, vol. lvi, Parts III and IV),

B. K. Das describes the result of dissecting Indian mammals for the purpose of ascertaining the frequency of the occurrence of truncated umbilical arteries. Of twenty-eight species examined, all but two exhibited this peculiarity. Whether the presence of these truncated arteries is correlated with existence in a tropical climate, or whether they are merely conspicuous embryonic vestiges of no particular function, it is impossible to decide until the mammals of other tropical countries are investigated.

In comparing the mammalian and reptilian coracoids, A. S. Romer (" The Comparison of Mammalian and Reptilian Coracoids," *Anat. Rec.*, vol. xxiv, No. 2, Sept. 1922) agrees that the mammalian coracoid is the posterior coracoid element of primitive and mammal-like reptiles, as stated by Broom and Watson. " The modern reptilian ' coracoid ' is homologous with the primitive anterior element and the epicoracoid of monotremes. The so-called epicoracoid of modern reptiles is a cartilage which may be compared with a variable anterior and ventral cartilage in extinct reptiles and a similarly placed cartilage in monotremes."

Papers of special importance to the systematic zoologist are those of W. R. B. Oliver on " A Review of the Cetacea of the New Zealand Seas "; Sir S. F. Harmer, " On Commerson's Dolphin and other Species of *Cephalorhynchus* "; C. F. Sonntag, " The Comparative Anatomy of the Tongues of the Mammalia " VII; and R. I. Pocock's " The External Characters of *Searturus* and other Jerboas, compared with those of *Zapus* and *Pedetes*," all in the *Proc. Zool. Soc. Lond.*, Part III, 1922.

Other important papers are :


Appleton, A. B., " On the Hypotrochanteric Fossa and Accessory Adductor Groove of the Primate Femur," *Jour. of Anat.*, vol. lvi, Parts III and IV.

Carey, E. J., " Studies in the Dynamics of Histogenesis. Intermittent Traction and Contraction of Differential Growth, as a Stimulus to Myogenesis, XI: The Dynamics of the Pectoralis Major Tendon," *Anat. Rec.*, vol. xxiv, No. 3, Oct. 1922.

Groebbels, F., " Der Hypoglossus der Vögel," *Zool. Jahr.*, vol. xliii, No. 4, 1922.

Kesteven, H. L., " A New Interpretation of the Bones in the Palate and Upper Jaw of Fishes," *Jour. of Anat.*, vol. lvi, Parts III and IV.

Smith, Sir F., " Anatomical Notes on the Accessory Organs of the Eye of the Horse," *Jour. of Anat.*, vol. lvi, Parts III and IV.

Sullivan, W. E., " The Function of Articular Discs," *Anat. Rec.*, vol. xxiv, No. 2, Sept. 1922.

Wood Jones, F., " On the Dental Characters of Certain Australian Rats," *Proc. Zool. Soc.*, Part III, 1922.


*General Experimental Zoology.*—A case of true hermaphroditism in the fowl is described by C. G. Hartman and W. F. Hamilton in the *Jour. of Expt. Zool.*, vol. xxxvi, No. 2, Aug. 20, 1922 ("A Case of True Hermaphroditism in the Fowl with Remarks upon Secondary Sex Characters"). The bird was a Rhode Island Red fowl, nine years old, and possessed an ovotestis and a testis both active. "The hermaphrodite displayed external characters and behaviour of both sexes." The ovotestis contained the so-called "interstitial" and "luteal cells." The latter are considered by the writers to be the endocrine cells of the ovary responsible for hen-feathering.

H. Erhard has carried out investigations on the reaction of some common Crustaceans to light ("Zur Kenntnis des Lichtsinnes einiger niederer Krebse," *Zool. Jahr.*, Bd. 39, Heft 1, 1922). *Cyclops*, *Chydorus*, and *Diaptomus* were found to be positively phototropic. The reaction depends upon the condition of adaptation. The sensitivity of the animals to brightness discrimination is scarcely less than that of the human eye. They follow in this respect the Weber Law. Reaction to the spectral colours is similar to that of the human eye with its "night vision," or the colour-blind eye. These animals also react to ultraviolet light.

L. T. Hogben and F. R. Winton have contributed a second paper on "The Pigmentary Effector System," to the *Proc. R. S.* (vol. xciv, No. B 658). This paper deals with an investigation as to the existence of a nervous mechanism of pigment control in the light of experiments carried out with frogs, on the section and stimulation of nerves and the administration of drugs. With the exception of caffeine, the only reagents found to induce melanophore contraction were those known to excite peripheral sympathetic nerve endings, and apart from pituitary extract, the reagent which induced expansion of the melanophores must have paralysed all sympathetic nerve endings. No unequivocal direct evidence has been advanced to demonstrate a nervous control of these pigment responses. The writers therefore conclude, "the possibility is indicated that the synchronous colour changes of Amphibia in response to normal environmental stimuli are determined mainly by endocrine influences."

After removing the parathyroid glands from the albino rat, F. S. Hammett has found that there is a marked increase in the size of the submaxillary glands. As the same result is not attained after thyro-parathyroidectomy, he concludes that "the cause of the enlargement is not attributable to any local irritation produced by the operative procedure. It is possible that the hypertrophy or hyperplasia is a response to an increased functional activity induced by the increased neural irritability resulting from the removal of the parathyroids" ("Studies of the Thyroid Apparatus, VI: The Response of the Submaxillary Glands of the Albino Rat to

Thyro-parathyroidectomy and to Parathyroidectomy," *Amer. Jour. of Anat.*, vol. xxxi, No. 2, Dec. 1922).

G. H. Parker has carried out a series of observations on the mode of locomotion of the mollusc *Strombus gigas* ("The Leaping of the Stromb, *Strombus gigas* Linn.," *Jour. Expt. Zool.*, vol. xxxvi, No. 2, Aug. 1922). He describes its mode of progression as "leaping," an act which involves the forward extension of the foot, its fixation in the substrate by its anterior and posterior ends, and a vigorous muscular contraction whereby the shell is thrown well forward, maybe as far as half its length.

"The Reaction of Living Cells in the Tadpole's Tail towards Starch, Agar-agar, Gelatin, and Gum Arabic," is the subject of a paper by E. R. and E. L. Clark (*Anat. Rec.*, vol. xxiv, No. 3, Oct. 1922). Of the substances experimented with, semi-cooked starch grains were found to exert a most intense attraction on leucocytes, which surrounded the granules, phagocytised the smaller ones, and in the course of a few hours transformed them into substances unstained by iodine. Boiled starch, agar-agar, gelatin, and gum arabic exerted a less powerful attraction for phagocytes. The other tissue cells showed no response to these introduced substances.

Other papers of special interest:

Erhard, H., "Kritik von J. Loeb's Tropismenlehre auf Grund fremder und eigener Versuche," *Zool. Jahr.*, vol. xxxix, No. 1.

Fleming, A., and Allison, V. D., "Further Observations on a Bacteriolytic Element found in Tissues and Secretions," *Proc. R.S.*, vol. xciv, No. B 658.

Hertwig, P., "Beobachtungen über die Fortpflanzungsweise und die systematische Einteilung der Regenwurmnematoden," *Zeit. für Wiss. Zool.*, vol. cxc, No. 4, 1922.

Titschack, E., "Die sekundären Geschlechtsmerkmale von Gasterosteus aculeatus L.," *Zool. Jahr.*, vol. xxxix, No. 1.

*Zoological Technique.*—In "Notes on Technique" (*Anat. Rec.*, vol. xxiv, No. 2, Sept. 1922), C. E. Buell describes a method of preparing whole mounts of early embryos and also a method of dissecting material embedded in paraffin wax.

F. A. McJunkin, in the same journal, describes a method of peroxydase staining with benzidin in paraffin sections of human material. This is the sixth of a series of reports on the mononuclear leucocytes of the blood.

Of special interest, also, is the following paper:

Malone, E. F., "Sharpening Microtome Knives," *Anat. Rec.*, vol. xxiv, No. 3, Oct. 1922.

**ENTOMOLOGY.** By A. D. Imms, D.Sc., Institute of Plant Pathology, Rothamsted Experimental Station, Harpenden.

*General Entomology.*—A third edition of Folsom's *Entomology* (Philadelphia, n.d., 502 pp., 5 pls., 308 figs.) has recently appeared. It is a well-arranged and thoroughly up-to-date textbook dealing with all branches of entomology other than ordinal taxonomy. The classified bibliography at the end of the work is particularly useful, and includes a number of 1922 references. G. H. Parker (*Psyche*, **29**, 127–31) brings to notice a possible instance of pædogenesis in *Calliphora erythrocephala*. This announcement, if confirmed, is of first-rate importance. In one experiment, 50 jars were set up with pieces of fresh meat and were examined 26 days later, when they were ascertained to contain no larvæ. On the following day 25 jars were each inoculated with a single newly hatched larva and 25 of the jars were retained as controls. After a further 12 days the controls were examined, but no larvæ were found in them: 3 of the infected vessels also contained no larvæ, those introduced into them having presumably died. In each of 20 infected jars a single larva was present, and of the two remaining infected vessels one contained 8 larvæ, and the other 21. The tests were carried out with such precautions that it seems impossible that the results are due to accident. It is noteworthy that the supposed pædogenesis only occurred during autumn: at the appropriate time the author intends to conduct an investigation of the larvæ in order to ascertain whether they contain parthenogenetic eggs or young. In *Quart. Journ. Mic. Sci.* (**66**, 4) are two papers on spermatogenesis. R. H. Bowen emphasises the essential parallelism existing between the production of sperms in Lepidoptera and other insects, particularly Hemiptera. H. G. Cannon describes certain details in the spermatogenesis of Anopleura. An up-to-date illustrated account of "Social Life among Insects" (The Lowell Lectures) is contributed by W. M. Wheeler as a series of articles in the *Scientific Monthly*, 1922. G. C. Crampton (*Can. Entom.*, **54**, 206–16, 222–35) discusses the relationships of the orders of insects from characters afforded by the wing venation. In *Phytopathology*, **12**, No. 5, is a symposium by several authors on insects as disseminators of plant diseases. The first case was noted in 1891, when Waite showed that fire blight was transmitted in this manner. There are now 16 or 17 bacterial diseases, and about 40 fungal diseases, in which insects play a part in transmission. H. M. Morris (*Bull. Ent. Res.*, **13**, 197–200) describes an apparatus which enables insects and other Anthropods, etc., to be separated from soil, by means of an arrangement of sieves of different sizes and a steady current of water. The same author (*Ann. App. Biol.*, **9**, 282–305) has investigated the insect and other invertebrate fauna of arable land at Rothamsted. A comparison of the fauna of manured and unmanured land is made, together with the depths to which various insects penetrate into the soil, and the bearing of such organisms in relation to agriculture.

*Coleoptera.*—T. H. Beare and H. Donisthorpe (*Ent. Month. Mag.*, 1922, 183) record *Aulonium ruficorne* Ol. and *Hypophlœus fraxini* Kugel from logs of Scots pine in the Forest of Dean, both species being hitherto unknown in the fauna of the British Isles. E. N. Pavlovsky (*Quart. Journ. Mic. Sci.*, **66**, 627–55) has a detailed memoir on the structure and biology of the larva of the water beetle *Hydrophilus caraboides*. P. H. Timberlake (*Proc. Hawaiian Ent. Soc.*, 1922, 121–33) has investigated the inheritance of colour variations of the lady-bird *Cœlophora inequalis*, and finds that the black form is recessive to the dominant normal and nine-spotted varieties. S. A. Graham (*Ant. Ent. Soc. Am.*, **15**, 191–200) has studied the venation of the hind-wings in a number of Coleoptera, and finds that the hypothetical venational type for that order does not differ greatly from that hypothetical type of Comstock and Needham for insects in general. In the case of Coleoptera it is characterised by the apical fusion of $R_3$ with $R_4$, and of $R_5$ with $M_1$. The Colorado potato beetle has recently appeared in the Gironde (*Bull. Soc. Agric. Fr.*, **54**, 250–2) over an area of about 100 square miles. A sum of approximately £20,000 has been voted for its control. A. M. Altson (*Ann. App. Biol.*, **9**, 187–95) describes the young larva of *Lyctus brunneus*. It appears that, at maturation, the first instar larva commences to feed upon the residual yolk contained in the anterior part of the egg, remaining within the chorion to do so. It takes three to five days to accomplish this, and does not commence to bore into wood until its second instar. A. W. Rymer Roberts (*ibid.*, 306–24) has a third instalment of his paper on the life-history of " wireworms " and provides a table of the larvæ of British Elateridæ based upon that of Henriksen. The metamorphoses of some Argentine Cassidinæ are described and well figured by A. G. Frers (*Physis*, **5**, 245–62). J. C. F. Fryer (*Journ. Ministry Agric.*, **29**, 748–49) gives an account of a new apple pest, *Anthonomus cinctus*, which has recently been found in Great Britain. It is suggested that it be known as the bud weevil from the fact that it attacks the buds of apple and, more especially, pear. The insect is prevalent in some parts of the Continent, but so far appears to be very local in Britain, and may be an indigenous species which has hitherto been overlooked.

*Lepidoptera.*—H. D. Peile (*Journ. Bombay Nat. Hist. Soc.*, **28**, 50–70) discusses the butterfly fauna of Mesopotamia, contributing notes on forty-four species. This fauna, like the flora, is more English in character than, for example, the fauna of southern France. In their work on *The Genitalia of* *the Group Tortricidæ of the Lepidoptera of the British Islands*, F. N. Pierce and J. W. Metcalf contribute the third volume on these organs. Their investigations have led them to add seven species to the British fauna: on the other hand, no structural differences in the genitalia were found to separate five pairs of species which have all hitherto been regarded as distinct. The rare event of adding a new species of the well-worked group of the Noctuidæ to the British list has recently occurred when J. J. Walker (*Ent. Month. Mag.*, 1923, 8) detected an example of *Cucullia lactucæ* W. V. among a collection of British Lepidoptera in the Oxford University Museum. J. D. Detwiler (*Can. Ent.*, **54**, 176–91) gives a very full, illustrated account of the ventral prothoracic gland in the larva of *Schizura concinna*. A. P. Jameson in his *Report on the Diseases of Silkworms in India* (Calcutta, 1922) discusses the subject more especially from the economic and historical standpoints. It appears that all the recognised silkworm diseases are found in India, and that those of the mulberry, muga, and eri worms are the same. The author states that the crux of the whole question is the "ryot." If improvements are to be effected, the village rearer will have to be instructed in the causes of the disease and induced to go in for improved methods of rearing. E. A. Cockayne (*Trans. Ent. Soc.*, 1922, 225–39, pls. v-ix) discusses cases of intersexual forms in *Plebius argus*. J. de Joannis (*Ann. Soc. Ent. Fr.*, **91**, 73–155) gives a revision of the cecidogenous Lepidoptera of Europe and the Mediterranean Basin, and enumerates sixty-two species, of which rather more than one-third are Tortricidæ.

*Diptera.*—E. Roubaud (*Comp. Rend.*, **174**, 964–66) discusses overwintering in various flies. True hibernation may occur as larvæ, pupæ, or imagines. In many cases the winter "sleep" of the imagines does not result from low temperatures: it is an expression of an internal rhythm. In *Musca*, *Stomoxys*, and *Drosophila* there is a uniform vital activity except in the presence of marked cold. In certain species of *Sarcophaga*, *Mydæa*, and *Lucilia* there are phases of unequal activity in the annual cycle. Broods rapidly developed, susceptible to temperature, are followed by a generation characterised by inertia or diapause which commences in autumn, but is not initiated by a lowering temperature. F. W. Urich, H. Scott, and J. Waterston (*Proc. Zool. Soc.*, 1922, 471–7) discuss the habits of a pupiparous Dipteron, *Cyclopodia greeffi* Karsch, which parasitises a flying fox in San Thomé. The female deposits the full-fed larvæ to parts of trees upon which the bats sleep, and in this situation they immediately pupate. A Chalcid, *Eupelmus urichi*, sp. nov., is described by Waterston from the puparia of the above insect. J. A. Sinton (*Ind.

*Journ. Med. Res.*, **9**, 132–62) enumerates a number of cases of myiasis in India and Persia describing the larvæ, puparia, and imagines of several of the insects concerned. Students of Diptera will be interested in an excellent paper on the larva of *Chaoborus crystallinus* (de G.) (= *Corethra plumicornis* F.) by S. C. Akehurst (*Journ. Roy. Micros. Soc.*, 1922, 341–72). The discovery of vestigeal thoracic limbs and ten pairs of spiracular rudiments is of particular interest, these and other features being survivals of a former terrestrial life. The gas contained in the tracheal reservoirs is probably secreted by the cells contained in tubes arising from the valve ends of those four sacs. The author, unlike the physiologist Krogh, is inclined to think that the integument is impervious and consequently takes no part in respiration—a view which is held by Frankenberg. W. B. Cartwright (*Can. Ent.*, **54**, 154–5) records a new example of "assembling," the species concerned being the Hessian fly. Females were confined in cages placed in the field, and on an average 145 males were attracted per 25 confined females; in one instance a single female attracted 165 males. G. H. Carpenter and his collaborators (*Journ. Dept. Agric. Ireland*, **20**, No. 4; **22**, No. 1) contribute the Fifth and Sixth Reports of their experiments and observations as to the life-history and treatment of Warble flies. In the Fifth Report it is demonstrated that the insect can be exterminated from an isolated area (Clare Island) by the systematic squeezing out and destruction of the larvæ from cattle. By persevering efforts, extending over seven months a year for six years, the cattle (about 450 in number) were rendered altogether free. In the Sixth Report it is shown that all results so far obtained indicate that the destruction of the adult larvæ by dressing the backs of cattle in spring is the most effective method of combating the pest. It is hoped that a wash of tobacco powder and lime, or some modification of it, will form an effective and safe remedy on a large scale. W. Bischoff (*Arch. Naturg.*, III, 1–50, 51–60) discusses the formation of the head in Dipterous larvæ. D. L. Van Dine (*Bull.* 1098, *U.S. Dept. of Agric.*) deals with the effect of impounding streams and converting swamp-like areas to lake-like conditions as a means of controlling the breeding of mosquito larvæ. After vegetation had been cleared away and provision made for a sufficiently high level of water, the method was considered successful. The non-breeding of *Anopheles* in the impounded water requires further investigation.

*Hemiptera.*—P. Marchal (*Compt. Rend.*, **174**, 1091–6) gives an account of the metamorphoses of the "ground pearls" *Neomargarodes trabuti*, from Algiers. The female is neotænic and ceases development in the third instar: the male undergoes two or three further ecdyses. Both sexes up to the third instar undergo a remarkable hypermetamorphosis as follows: First Instar: primary hexapod migratory larva. Second Instar: apodous, cystoid, fixed larva. Third Instar: hexapod Melolonthoid mouthless larva. S. R. Christophus and F. W. Cragg (*Ind. Journ. Med. Res.*, **9**, 445–63) describe the so-called "penis" in *Cimex lectularius* and the sexually modified segments of the female. In the latter sex there are two apertures —a copulatory orifice and one for oviposition. E. E. Green has completed his standard work on the "Coccidæ of Ceylon" in issuing the fifth volume of that treatise. The distribution of the organ of Berlese among the Clinocoridæ is discussed by K. Jordan in the new publication *Ectoparasites* (**1**, part iv). This structure has been supposed to be an organ of copulation, receiving the spermatozoa direct from the male and passing them on to the body-cavity whence they ultimately reach the oöcytes. J. H. Kershaw and F. Muir (*Ann. Ent. Soc. Am.*, **15**, 201–12) describe the genitalia of the auchenorhynchous Homoptera. The gonopore lies between the eighth and ninth sterna, or at the base of the ninth sternum, and the three pairs of gonapophyses are homologous in the two sexes. J. Edwards (*Ent. Month. Mag.*, 1912, 202–7) gives a list and a tabular synopsis of the British species of the Jassina division of the Jassidæ, and in the same journal (p. 191) F. Laing records one interesting addition to the fauna of Britain in *Phylloxera salicis* Licht. from bark of willows in Norfolk.

*Orthoptera and Dermaptera.*—Part III of the *Faune de France* (1922) is devoted to these two orders, and is contributed by L. Chopard. It forms a useful and profusely illustrated synopsis of the insects with which it deals. B. P. Uvarov (*Ent. Month. Mag.*, 1922, 277) records nymphs of a Phasmid, possibly those of a species of *Menexenus*, at an altitude of 16,500 ft. in Tibet, where they were found during the recent Mount Everest Expedition. The same author (*ibid.*, 211) records *Stauroderus vagans* (Eversm.), a grasshopper, new to the fauna of Britain, from the New Forest. F. Brocher (*Ann. Soc. Ent. Fr.*, **91**, 156–64) contributes some new researches on the circulation of the blood in *Periplaneta.*

*Hymenoptera.*—C. T. Gimingham (*Ent. Month. Mag.*, **58**, 226–8) records the parasitisation of the larvæ of *Bruchus rufimanus* by the Braconid *Sigalphus luteipes* Thoms. in Warwickshire. Out of three lots of the *Bruchus* totalling over 1,700 individuals, the parasitism ranged from 51·1 per cent. to 72·3 per cent., the Bracond reducing the number of beetles reaching the imago by more than half. H. Donisthorpe (*Trans. Ent. Soc.*, 1921, 307–11) enumerates insects and other Arthropoda which mimic ants. He concludes that, since the latter insects are on the whole well protected, it is profitable for other Arthropoda to resemble them. W. M. Wheeler and collaborators (*Bull. Amer. Mus. Nat. Hist.*, **45**, 1921–2, 1139 pp.) have published one of the most extensive myrmecological contributions that has yet appeared, and deal with the ants of the American Museum Congo Expedition. It is impossible within the limited space available to do justice to this series of memoirs, but special mention may be made of J. Bequaert's most interesting article on ants in relation to plants, which should be read by both entomologists and botanists.

*Other Orders.*—R. Vogel (*Zool. Jahrb. Anat.*, **42**, 229–58) has an important paper on the structure and function of the fore-gut and proboscis in *Pediculus vestimenti*. E. Hegh's *Les Termites* (Bruxelles, 1922, 756 pp., 460 figs., and 1 map) is a general treatise on the Isoptera. R. J. Tillyard (*Bull. Ent. Res.*, **13**, 205–55) provides a much-needed account of the metamorphoses and biology of the primitive Australian moth-lacewing *Ithone fusca*. W. A. Clemens (*Cant. Ent.*, 1922, 77–8) records a case of parthenogenesis in the mayfly *Ameletus ludens*, females only being produced. The various methods of adaptation of mayfly nymphs to life in swift streams are discussed by G. S. Dodds and F. L. Hisaw (*Proc. Am. Soc. Zool.* in *Anat. Rec.*, **23**, 10).

**ANTHROPOLOGY.** By A. G. THACKER, A.R.C.S., Zoological Laboratory, Cambridge.

IN the latest number of the *Journal of the Royal Anthropological Institute* (January–June 1922, vol. lii) there is a very interesting article by Prof. C. A. Nordman dealing with the Neolithic cultures of Scandinavia, and especially with their relationship to contemporary cultures in Finland. The article is in some sense a reply to a paper on this subject which Mr. H. Peake contributed to the *Journal* in 1919, and which I discussed briefly in these pages in October 1920. The story told by Prof. Nordman differs materially from that of Mr. Peake. Nordman mentions that the oldest known culture of Scandinavia is represented by a few implements made of reindeer-antler, and that apart from these few relics, the famous Maglemose (Mullerup) culture is the earliest cultural phase in the North. The Maglemose culture dates from the time when the Baltic was cut off from the ocean and constituted what is known as the "Ancylus Lake." The implements of the Maglemose people were chiefly of bone. The culture is roughly contemporaneous with the Azilian Age of Western Europe; but Nordman thinks that it was derived, not from the Azilian, but from the Magdalenian of the West. Farther east, in what afterwards became the Baltic provinces of Russia, another culture, represented mainly by implements of stone, existed contemporaneously with the Maglemose culture; and these stone-workers pressed north into Finland. This early civilisation of Finland is known as the Suomusjarvi culture; and speaking of this culture and that into which it immediately developed, Nordman says that most Finnish archæologists believe that "the originators of this civilisation were the forerunners of the Finno-Ugrian peoples." In Denmark the Maglemose culture developed directly into the culture of the kitchen-middens, the geographical conditions having changed remarkably in the meantime—changed, by the way, with most astonishing rapidity, unless the accepted chronology is totally erroneous—the Baltic being once more oceanic and the climate genial and appreciably warmer than at the present day. During the same period the Suomusjarvi culture developed and improved, and seems to have spread over a wide area; it was now characterised by earthenware vessels ornamented with comb impressions. The next stage is the appearance in Denmark of a megalithic civilisation, which is totally new, and is obviously an incursion from south-western Europe. Whether there was any great ethnic infusion accompanying the north-eastern spread of megalithic civilisation, it is at present impossible to say. After the megalithic people, there came another people who buried their dead in single earth-graves and were addicted to the use of battle-axes; this "battle-axe culture" has now been definitely isolated from the confusion of early Scandinavian relics, but the men who were responsible for it are not yet known. The battle-axe culture spread to Finland, and seems to have imposed itself upon the people of the greater part of both Scandinavia and Finland so thoroughly that at the very end of the Neolithic Age and in the Bronze Age there was a homogeneous culture (though by no means a homogeneous race) throughout Denmark, the Scandinavian Peninsula, and Finland. Nordman believes that in the spread of this battle-axe culture we see the arrival of the Teutons in the north, the culture itself being most closely related to the contemporary civilisation of Central Europe, whence it obviously came. Later, about the beginning of the Christian Era, there was a resurgence of native Finnish culture in Finland, owing to contact with and probably immigration from the Baltic provinces.

This in brief outline is Nordman's story. It will be seen that the early Scandinavian cultures have been to a considerable extent disentangled the one from the other. On the other hand, scarcely anything is known of the somatology of the peoples responsible for the cultures, and therefore on the ethnological side the story is almost pure hypothesis. Peake writes a short rejoinder in the same number of the *Journal*, in which he states that the Battle-axe People were identical with the Bronze Age invaders of Britain. The chief desideratum is, however, direct skeletal evidence ; on this side of the question, the Scandinavians are in much worse case than we are in Great Britain. Nordman's contention that there were no Aryans, Teutonic or otherwise, in the north before the coming of the Battle-axe People will not be readily accepted. On the racial question, we can at present hardly do better than look backwards from the earliest historic conditions ; but those conditions do not seem to favour the interpretation that there had been a mere imposition of a Teutonic ruling class.

The following papers may also be noted :

In the *Journal of the Royal Anthropological Institute* (vol. lii, January–June 1922) : "The Unity of Anthropology," being the presidential address of the late Dr. W. H. R. Rivers ; and the "Anthropology of the Chiltern Hills," by H. Bradbrooke and F. G. Parsons. And in the *American Journal of Physical Anthropology*, vol. iv, No. 4 (October–December 1921) : "Age Changes in the Pubic Bone," by T. Wingate Todd. And in the same *Journal*, vol. v, No. 1 (January–March 1922) : "A Remarkable Human Lower Jaw from Peru," by G. G. MacCurdy ; "New Discoveries of Neandertal Man at La Quina and La Ferrassie," also by G. G. MacCurdy ; and "Observations on Age Changes in the Scapula," by W. W. Graves. And in the *Annals of Archæology and Anthropology*, vol. ix, Nos. 1 and 2 (March 1922) : "The Influence of Egypt on Hebrew Literature," by A. B. Mace ; and "Problems of Megalithic Architecture in the Western Mediterranean," by E. T. Leeds. And in the *Geographical Review*, vol. xi (1921) : "The Evolution and Distribution of Race, Culture, and Language," by Griffith Taylor. And in the *Proceedings of the Royal Physical Society*, vol. xx (1921) : "The Prehistoric Find at Piltdown," by Prof. Waterston. And in *Man* (December 1922) : "Notes on the Chronology of the Ice Age," by M. C. Burkitt ; and "Man and the Ice Age," by S. H. Warren.

## MEDICINE. By R. M. Wilson, M.B., Ch.B.

The most important piece of work published during the past year was certainly that of Banting at Toronto, in which he succeeded in isolating the active principle of the pancreas and so opening the way to a new and specific treatment of diabetes. Banting's original idea seems to have been that earlier pancreatic extracts failed because the enzymes of the gland, its external secretion, exercised a destructive effect on the internal secretion now known as "Insulin."

With this idea in his mind he set to work to secure a supply of insulin which should be free of contamination with the enzymes. The earliest method employed by him was to tie the pancreatic duct of a dog and then allow the animal to live for a period long enough to ensure the destruction of the external secreting portion of the gland.

When destruction might be supposed to be complete the dog was killed and an extract of the remaining portions of the gland prepared—that is to say, an extract of the islands of Langerhans.

This extract was tested on a second dog which had previously been deprived of its pancreas and which was, in consequence, suffering from diabetes mellitus. The sugar swiftly disappeared from both blood and urine and the dog became much better in every way.

A great deal of work has been done since this early experiment. It has, however, only served to confirm the original observations. Happily a method of alcoholic extraction has been devised which obviates the necessity of repeating the elaborate technique of the first attempts. The "insulin" can be recovered from ordinary "slaughter-house" glands.

The work was performed in Prof. McLeod's laboratory and under his general supervision. In order to protect the public a patent was taken out, and the British rights in this matter have been presented to the Medical Research Council. This body sent Dr. H. H. Dale to Toronto to investigate, and he is now working out improved methods of extraction of the anti-diabetic internal secretion. These, it is stated, are already so far developed as to promise a high insulin yield per pancreas —a matter of very great importance.

The new "insulin" has been tried in many cases of diabetes, with marked success. After a single injection sugar may so far disappear from the blood as to cause symptoms of acute sugar-want, and therefore great care in administration is essential. In cases of acidosis the extract "works like a charm," and it is also very successful where young subjects are concerned. Its disadvantages, at present, are that it must be injected and that certain difficulties of dosage are apt to present themselves. Treatment must, of course, be continued indefinitely. If it is stopped the patients, who have put on flesh and improved in spirits, quickly relapse to their former condition.

It is as yet impossible to form anything like a final estimate of this work. If, however, the early promise is fulfilled, medicine will have acquired a new weapon of the most important kind. For what thyroid treatment has done for myxœdema and cretinism, insulin treatment bids fair to achieve for diabetes.

. . . . . .

The third annual Report of the Medical Research Council has been issued. It treats of a wide variety of subjects, most of which have already been mentioned in these columns. Special reference is made to Dr. Harriette Chick's discovery of the action of sunlight in augmenting the supply of vitamin A, fat-soluble vitamin, and of her subsequent work on artificial light produced by the mercury vapour quartz lamp. A full report of these most important studies is being prepared, but it can now be taken as established that the violet rays of the spectrum exercise a special effect on the human organism, enabling it to maintain health on a greatly decreased quantity of animal fat. It is likewise established that such a commodity as cod-liver oil represents a form of " bottled sunshine."

The epidemiological experiments on a colony of mice have been continued, and the further fact been recorded that if a large colony be split up into numerous sub-colonies at the moment of the first appearance of an epidemic, this epidemic will be, to some extent, reduced in virulence. It is suggested that poultry-keepers and other farmers of small animals might put this knowledge into practice at once, dividing up their stock into small parcels whenever threatened by disease on an epidemic scale.

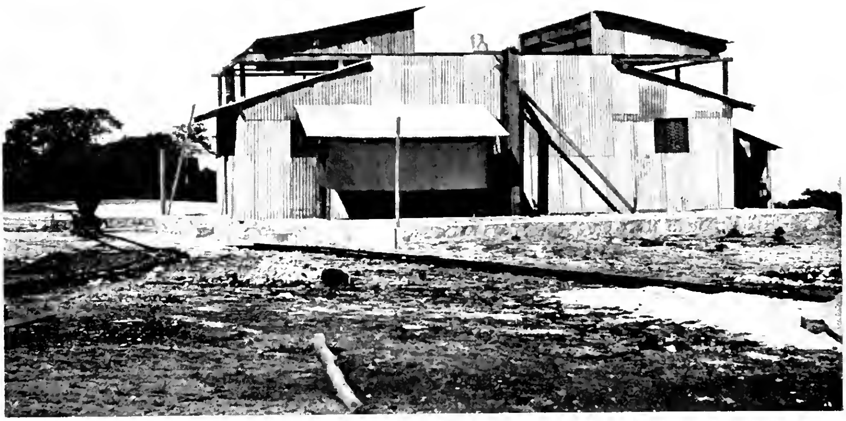
# ARTICLES

## THE BRITISH ECLIPSE EXPEDITION TO CHRISTMAS ISLAND

By H. SPENCER JONES, M.A., B.Sc.
*Chief Assistant, Royal Observatory, Greenwich*

The inception of the popular attention which has within the last few years been focused on Einstein's Generalised Theory of Relativity may be traced back to the report to the Royal Society of the results obtained by the two expeditions sent out under the auspices of the Joint Permanent Eclipse Committee of the Royal and the Royal Astronomical Societies to observe the eclipse of 1919, May 29. It was at that eclipse that the first really serious attempt was made to test whether rays of light were bent by the gravitational field of the sun, and if so, by what amount. The expedition to Brazil was favoured with excellent conditions during the eclipse, whilst that to Principe, though considerably interfered with by cloud, was fortunately able to secure some observations which, incomplete as they were, tended to support those obtained in Brazil and to join with it in confirming the conclusion deduced by Einstein from his theory. The results were announced at a meeting of the Royal Society in November 1919 and attracted widespread attention. Many who had hitherto been very sceptical with regard to the theory began, as a result of this further success which it had gained (its success in accounting for the perihelion motion of the planet Mercury being already well known), to look upon it with more favour. Others took up the attitude that further confirmation was desirable before such a radical revolution as the theory demanded in scientific thought could be accepted.

It was unfortunate that the results obtained at the eclipse of 1919 were not such as to gain general acceptance. Two instruments were used in Brazil and their results were discordant. As has been very general on eclipse expeditions, horizontal telescopes had been employed, the light from the sun



OBSERVING HOUSE FROM NORTH
Showing end of telescope and illustrating protection of latter from wind

FLYING FISH COVE, CHRISTMAS ISLAND.

being reflected into the telescope tube by a cœlostat mirror. Such instrumental equipment is very much easier to set up in a temporary fashion than an equatorially mounted telescope. The discordances in the 1919 results were traced to a slight astigmatism of the cœlostat mirror due to its surface having been unequally heated by the sun during the eclipse. In the case of one of the instruments this was shown by the diffuseness of the star images. The images given by the other instrument were quite sharp. It was the former instrument which gave the results which did not agree with the Einstein theory.

On account of the importance for scientific thought generally of a decisive verdict on the question, it was decided by the Eclipse Committee that a further attempt must be made to determine the gravitational deflection at the eclipse of 1922, September 21. The circumstances of this eclipse were not so favourable as were those of 1919 as the stars in the neighbourhood of the sun at the time of eclipse were much fainter. Preliminary examination of the field at Greenwich showed, however, that the stars were sufficiently bright to obtain good results under fairly favourable conditions. In order to avoid the distortion which had been produced by the heating of the cœlostat mirror it was decided to use a telescope mounted equatorially. For this purpose, the astrographic telescope of the Royal Observatory, Greenwich, seemed most suitable. This instrument has an aperture of 13 inches and a focal length of 11 feet. It was therefore of sufficient focal length for the purpose in view, and at the same time not so large as to make it impossible to erect it in an out-of-the-way part of the world.

The path of totality of the eclipse passed across the Maldive Islands, Christmas Island, and Australia from the north-west to the south-east. There was nothing to commend the Maldives, which are not easily accessible, are very unhealthy, and where there might have been trouble from vibration due to the surf. Christmas Island was easily accessible and had excellent facilities for the landing and erection of heavy instruments. It possessed the further advantage that the eclipse occurred at local noon, so that the sun was very high in the sky at the time of eclipse. This is of some importance when faint stars have to be photographed, as atmospheric absorption is then a minimum. The north-west coast of Australia is an inhospitable region, difficult of access, and as landing is only possible in surf-boats, the use of heavy instruments was out of the question. Incidentally, it may be mentioned that the Australian Government subsequently offered many facilities to expeditions which decided to go to the north-west coast, but at that time our preparations were too far advanced to make it possible to alter the plans which had been decided upon, even had it been possible to land the astrographic telescope there. In Australia, farther to the south-east, the sun was too low at the time of eclipse for any station there to be considered. Christmas Island therefore seemed the most suitable station. Although its climate was not so favourable as that of the north-west coast of Australia, where rain or cloud in September is almost unknown, it appeared sufficiently favourable for the expedition to have a good chance of success. September and October are usually the two best months of the year with, as a rule, fairly settled and dry weather. It was therefore selected as the station. It was somewhat to the north of the central line of totality, but by going as far south as possible on the island a duration of nearly five minutes was obtainable, which was adequate, given good weather, for an accurate determination of the gravitational deflection.

A new mounting for the astrographic telescope was obtained from Sir Howard Grubb & Sons, suitable for the latitude of the Island, to which the existing clockwork and electric control gear of the telescope was fitted. A new counterpoise system was also provided. Special aluminium plate-holders were designed and made at the Royal Observatory which could be readily changed during the eclipse, and which enabled each plate to take up a definite three-point bearing on the breech-end of the telescope.

The comparison plates of the eclipse field, which were to be used in conjunction with the eclipse plates themselves for the determination of the deflection, were to be obtained about three months before the eclipse, when the field could be photographed shortly after sunset. It was decided to use the opportunity of a large telescope mounted in a stable manner near the Equator to combine with the eclipse some useful astronomical work. This consisted of the determination of the photographic magnitudes of stars in selected regions of the southern sky, by taking photographs in which a southern region was compared with a northern region. The magnitudes of the stars in the northern regions which were to be used had previously been determined at Greenwich by direct comparison with the standard area around the North Pole. A means would thus be provided by which observers in the southern hemisphere would be enabled to determine the photographic magnitudes of stars on the scale which has been standardised for the northern sky. Such means is at present lacking. This programme required at least five months for a sufficiently wide area of the southern sky to be covered, which meant that, allowing about five or six weeks for the erection of the telescope and an observing house and for the testing and adjustment of the telescope, the observers should leave England about the end of January.

The observers, Mr. H. Spencer Jones, Chief Assistant, and Mr. P. J. Melotte, Junior Assistant (Higher Grade) of the Royal Observatory, accompanied by Mrs. Spencer Jones, left Liverpool on January 28 by the Blue Funnel s.s. *Mentor*, arriving at Singapore on February 26. The s.s. *Islander*, belonging to the Christmas Island Phosphate Co., left Singapore on March 9 and arrived off the Island on the 13th. Unfortunately, there was a bad spell of weather then prevailing and it was not possible for the *Islander* to tie up and discharge her cargo until March 23.

The Island is a place of considerable interest. It is of approximately the same size as the Isle of Wight, very lofty —the highest point being about 1,100 feet above sea-level— with steep cliffs and densely covered with jungle. It is the only tropical island of large size which was until the last few years uninhabited. It forms the top of a lofty submarine mountain, the sides of which are very steep. Some of the greatest sea depths recorded occur between Christmas Island and Java, and most of the earthquakes which occur in Java have their origin under the sea between the two islands. A seismograph, supplied by the Seismological Committee of the British Association, was set up by the expedition and has been left on the Island so that daily records may be obtained which, studied in conjunction with those obtained in Batavia, should provide some valuable information for the study of these earthquakes. Earthquake tremors are from time to time felt on the Island, one such occurring during our stay, but unfortunately before the seismograph was recording.

The Island seems to have been formed by a process of successive volcanic upheaval, for traces of coral are to be found on the more or less level shelves which alternate with steep cliffs and indicate the stages of the upheaval. The Island consists mainly of limestone which outcrops everywhere, the depth of soil being in general very small. The phosphate rock which makes the Island so valuable has been formed through the interaction between the limestone and the guano in past ages. It has been found on three of the promontories of the Island. The central portion is a sort of saddle somewhat lower than these points, and it is probable that the deposits were formed at a time when only these points projected above the sea-level.

Although the Island had been visited several times before it was finally occupied, it was not until the late Sir John Murray discovered the presence of the extensive deposits of phosphate, as a result of the *Challenger* expedition, that its value was realised. He was instrumental in persuading the British Government to take the Island over and formed a company for working the phosphate, which secured the lease of the Island. This company, known as the Christmas Island Phosphate Co., has in the twenty-five years or so of its existence developed the Island very considerably. The European members of the staff have comfortable bungalows, with electric light, and a good water supply which is pumped along a pipeline from the other side of the Island. There is a small ice plant, a cold storage plant has just been installed, and a wireless telegraph plant for communication with Singapore and the Cocos Islands is now in course of erection. The Company's own steamer, the *Islander*, runs monthly between the Island and Singapore carrying mails, food supplies, stores of all sorts, members of the staff going on or coming from leave, and Chinese coolies from time to time. The labour force is almost entirely Chinese, with the exception of a few Malays who attend to the shipping. The phosphate is exported in its raw state, and does not receive treatment for its conversion into superphosphate. In the face of considerable disadvantages, two piers for ships have been put up, so that loading is a comparatively simple process, a ship of 6,000 tons being loaded in about four days. The phosphate is exceptionally pure; the extent of the deposits is not known with any certainty, but there are at least some millions of tons.

The Island does not, unfortunately, possess a sheltered roadstead. The steeply shelving sea bottom renders it impossible to construct any sort of breakwater. Ships approaching the land drop a long length of cable and gradually approach the pier. The anchor catches against the steep bottom, and mooring lines are then put out to hold the vessel to mooring buoys which are anchored to the sea bottom. The Company possesses its own pilots, and has a diver for attending to the moorings. In general the prevailing wind is from the south-east, and as the settlement at Flying Fish Cove is on the north of the Island, ships can usually lie at the piers in perfect safety, though as a measure of precaution steam is always kept up. But in the rainy season, from about November to April, spells of northerly winds, accompanied by squally weather and a heavy swell, are not uncommon. On such occasions, ships have to lie off the land until there is a change of wind and the swell dies down. During these winter months, ships rarely call for phosphate, the export being arranged for the summer months, when unsettled weather is the exception.

It so happened that the expedition arrived just at the commencement of one of these spells of unsettled weather.

The writer was able to land from a small boat on the other side of the Island when the mails were landed, but Mr. Melotte and the instruments had to remain on board for nearly two weeks until there was a change of weather. During that time I was able to get the foundation prepared for the instrument. The site chosen was at the south end of the Island. A new quarry is just being opened there, and a railway has been constructed across the Island to bring the phosphate into the settlement. But for this railway, it would not have been possible for the instruments to have been erected there, as the Island is very densely covered with jungle. The telescope was erected just at the terminus of the railway, on a terrace which had been levelled in preparation for the erection of coolie lines. The pier for the telescope was built up from the solid limestone rock, so as to give a perfectly stable foundation, and was constructed of lumps of limestone, cemented together with concrete.

As the expedition was remaining for about six months on the Island, it was necessary to have a more substantial housing for the telescope than is customary on eclipse expeditions. A house had been designed by me before leaving home, and this was kindly erected for us by the Company. It consisted of a wooden framework covered with corrugated iron. The total area was 40 by 20 ft. The observatory proper had an area of 20 ft. square. To east and west of it were two rooms each of 20 by 10 ft., which served respectively as a living-room and a dark-room. The central portion of the roof was constructed to slide back in two halves to east and west, running on rails with double-flanged wheels over the two rooms previously mentioned. The roof was moved by means of cables wound twice round double-flanged wheels, and could be opened without difficulty by one person. The walls of the house were 12 ft. 6 in. high and afforded considerable protection against the wind, which in general was fairly strong.

The erection of the telescope proceeded without hitch. We were assisted by Chinese coolies who worked splendidly. The manner in which they lifted heavy parts weighing several hundredweights by man-handling, which we would ourselves have lifted with shear legs and tackle, was surprising. The only difficulty arose, before the observing house was completed, from the innate curiosity of the Chinese. They cannot resist the temptation to abstract any small piece of brass, etc., which they can detach. This they regard as a good "joss." The difficulty was overcome by warning them that the telescope took photographs, and if any of them were to touch it, it would take a photograph of them and they would be detected. Thereafter it was left severely alone.

By the end of April the observing house was completed, the telescope was erected, and the various adjustments had all been made. By this time we had begun to realise that the weather was going to give us trouble. The sky was never completely free from cloud. Not only was there, in general, a fair amount of low cumulus which would drift rapidly across the sky, so that at one instant it might seem almost cloudless and a few minutes later almost completely cloudy, but there was always a certain amount of very high thin cirrus which made the sky non-uniform and therefore useless for photometry, for which a uniform sky is the prime essential. This trouble persisted to the end, and during the whole period of my stay on the Island, I never once saw the sky completely cloudless.

During June and July we secured a very good series of comparison plates of the eclipse field. These told us what we might expect to get during the eclipse itself under various conditions. They were also, of course, required for use in conjunction with the plates to be secured during the eclipse for the determination of the gravitational deflection. Using an aperture of 7 in., under good conditions eleven stars were obtainable with an exposure of ten seconds. With moderate conditions most of these were obtainable, whilst it would have been poor conditions which did not give them with an exposure of twenty seconds. It is of importance to give the correct exposure ; with too short an exposure the star images do not appear, with too long, they are drowned in the corona. The correct exposure to give is the shortest exposure which will show good measurable star images. But it must be remembered that the duration of totality is so short that in order not to waste a second the programme has to be carefully rehearsed beforehand and therefore cannot be changed at the last moment. Sufficient latitude has therefore to be allowed in forming the programme to ensure that something of value can be obtained whether the conditions are good or moderate.

The special feature of the method which we tried was that besides the region of sky around the sun an area some degrees away was to be photographed. The reason for this was as follows. Even though there were no gravitational displacement, it would not necessarily follow that the positions of the stars would be found to be the same on the eclipse plates and on the comparison plates. For the scale of the telescope might be different for the two series, one of which has been taken in the daytime and the other at night when the temperature is lower. However great the precautions one takes, it is not legitimate in the case of these delicate measures to assume that the scale remains constant. It follows that the gravitational displacement and the change of scale have to be disentangled from one another on the plates. A little reflection will show that, under these circumstances, it is only possible to measure the difference of the displacements between the stars nearest the sun and those on the plates farthest from it. The resulting value of the gravitational displacement has therefore only about half the weight which it would possess if the scale could be determined independently. But now suppose that another region of the sky is photographed on both the comparison and the eclipse plates, the chosen region being at about the same altitude as the eclipse field. Then this region enables the scale to be determined so that the full amount of the deflection can be deduced from the eclipse field itself. This was the method that was tried. It possesses the disadvantage that the position of the telescope has to be changed during totality, and should an error occur in the setting, valuable photographs would be lost. The method was well adapted for use with our telescope, which possessed an accurately divided setting circle. By marking the circle with small strips of white gummed paper the telescope could easily be moved from the one position to the other in twelve seconds of time to an accuracy of one second in right ascension. It was not necessary to look at any faint graduations, and the setting could be made as well in the dim light of a total eclipse as during broad daylight.

The duration of totality was estimated as nearly five minutes, and the programme of observations which I decided upon was as follows, using 7-inch aperture :

| No. of Plate. | Field. | Exposure. | Times from commencement of totality. |
|---|---|---|---|
| | | *Seconds.* | *Seconds.* |
| 1 | Scale | 10 | 0– 10 |
| | Eclipse | 10 | 22– 32 |
| 2 | ,, | 20 | 44– 64 |
| 3 | ,, | 20 | 76– 96 |
| 4 | ,, | 10 | 108–118 |
| | Scale | 10 | 130–140 |
| 5 | ,, | 10 | 152–162 |
| | Eclipse | 20 | 174–194 |
| 6 | ,, | 10 | 206–216 |
| | Scale | 10 | 228–238 |

If the duration of totality were to prove shorter than anticipated, the last exposure could be shortened. If the sky were somewhat cloudy, the first four plates to be secured would enable a reasonably good determination of the deflection to be made without losing much time in changing the position of the instrument. With good conditions ample material would be available for an excellent determination.

The programme was carefully rehearsed beforehand. In the rehearsals we were assisted by three of the British employees of the Phosphate Company. In order to avoid causing vibration to the telescope, which would have spoiled the star images, the exposures were made by means of a shutter held by hand in front of the object glass. The exposures were given by the writer, seated on a platform supported from the roof of the observing house. From there directions were given to Mr. Melotte below when to change the plateholders or to move the position of the instrument. Seconds were counted by one of our voluntary helpers from the beats of the controlling pendulum, and the exposures were estimated from these counts. The roof of the observatory was kept closed until shortly before totality in order to avoid the telescope getting heated up. It was only opened then sufficiently for the required amount of movement, so that the telescope was almost completely sheltered from the disturbing effects which wind might have caused.

The rehearsals all passed off well, and we looked for such results as would have decisively settled the amount of the deflection. The weather, which during the whole of our stay on the Island was generally unsettled, seemed at last to have set in fine. For several days preceding the eclipse, it would have been possible to have secured good observations. But, unfortunately, there was a change on the very day of the eclipse. I arose early, before dawn, and the sky was then completely covered with thick clouds. Somewhat later, heavy rain set in and our hopes fell to zero. But about 9 o'clock signs of improvement began to appear, the clouds gradually broke up, and half an hour later the sky was about the clearest which I have seen during the whole of my stay on the Island. The definition then was extremely good. But we had unfortunately still an hour and a half to wait for totality. The clouds began to gather again; first contact of the sun and the moon was well observed. Thereafter, it steadily grew more and more hopeless. There was a short break about twenty minutes before totality, but after that the sun was not seen again. The commencement of the total phase was dimly seen through cloud. One plate was exposed, first on the scale field and then on the sun. Owing to the cloud, it shows no stars, but a faint coronal ring is seen. But then even the glow of the corona through the clouds was lost, and the sun was not seen again until after the last contact, heavy rain following. So ended our hopes. Our disappointment it is impossible to describe. It seemed cruel to be sitting unable to do anything whilst the few valuable minutes for the coming of which so much preparation had been made were passing beyond recall.

Good weather conditions prevailed in Australia, and it is to be hoped that the well-equipped expedition from the Lick Observatory has secured observations which will settle the Einstein deflection. At the time of writing, the results which have been obtained by this expedition have not been announced, and the scientific world is eagerly awaiting news. If, from one cause or another, the question still remains open, it will be necessary to make a further attempt at the eclipse of September 10 next. The field of stars around the sun on that occasion is not very favourable. The stars are all faint, so that rather long exposures will be necessary. The near stars will then be lost in the glare of the corona, so that to obtain a good determination of the deflection, it is particularly to be desired that the method described above of photographing a scale field on the eclipse plates should be adopted. Its feasibility has been established. But after the next eclipse, it will be some time before another opportunity will arise of testing the theory. No British expedition is likely to be sent out to observe next September's eclipse if the Lick results are found satisfactorily to settle the matter. If they do not, it is very probable that a British expedition will go to California to try once more.

Before closing this account, mention must be made of the generous help afforded by the Christmas Island Phosphate Company. It was not possible to go to the Island without being dependent upon the Company in many ways, for supplies of labour, for materials of various sorts, for transport, etc. The Company conveyed the observers and the instruments in their steamer from Singapore to Christmas Island and back, supplied the labour required for unpacking, for erecting the telescope, for dismantling it after the eclipse and for repacking. They supplied both materials and labour required for the observing house. In many other ways we were dependent upon them, and although I felt at times that they were only able to meet our wishes at some inconvenience to their own work, everything possible was done to help us. All these services were given entirely free of charge to the expedition. Their kindness added to our regret that we were not able to return without something more to show for all that had been done for us.

Our thanks are also due to the Blue Funnel Steamship Company, which conveyed all our instrumental equipment from Liverpool to Singapore and back from Singapore to London, without charge.

# THE OXIDATION OF CANE SUGAR BY NITRIC ACID

By F. D. CHATTAWAY, F.R.S.

For over a hundred and fifty years the action which takes place when cane sugar is oxidised by nitric acid has attracted the attention of chemists and its spectacular character, from the torrents of nitrogen peroxide evolved, still makes it a favourite laboratory experiment. It has considerable historical interest, for it was from the product of this action that Bergman about 1776 first isolated oxalic acid.

From the testimony of several of his friends it appears that Scheele had identified the acid shortly before, though whether he obtained it from sugar or from wood-sorrel is not clear, for he never published any account of his work.

Thomson, in his famous *History of Chemistry*, writes: "That Scheele has nowhere laid claim to a discovery of so much importance as that of oxalic acid, and that he allowed Bergman peaceably to bear away the whole credit, constitutes one of the most remarkable facts in the history of chemistry."

It is, however, to Bergman that we owe the first published account of the properties of oxalic acid and of its production from sugar. He regarded the acid as contained in the sugar and as being liberated from it by the action of the nitric acid, for he thus begins his treatise:

"Sugar being justly considered as an essential salt, it will readily be granted that it contains an acid. This acid may be separated and exhibited in a crystalline form by the following process." He then describes the action of nitric acid upon it as follows:

"Let one ounce of the finest sugar in powder be mixed in a tubulated retort with three ounces of strong nitric acid whose specific gravity is nearly 1·1567. When the solution is completed and the most phlogisticated part of the nitric acid has flown off, let a receiver be luted on and the solution gently boiled; in this process an immense quantity of nitrous air is somewhat violently discharged. When the liquor acquires a dark brown colour let three ounces more of nitric acid be poured on and the boiling continued until the coloured and smoking acid has entirely disappeared. Let the liquor in the retort be then poured into a larger vessel, and upon cooling small quadrilateral prismatic crystals are found adhering together at an angle generally of about 45°. These, collected and weighed on bibulous paper, weigh 109 grains."

Apparently no more detailed account of the preparation of oxalic acid by this method, or of the yield obtained, was published until Thomson, some eighty years later, re-investigated the action and described what he found to be the most advantageous procedure. For nearly another eighty years little further attention has been given to the subject, and oxalic acid has been generally regarded as the sole end-product.

It might have been thought, from the number of times sugar has been oxidised for the preparation of oxalic acid and from the number of chemists who at different times have carried out the operation, that nothing remained to be discovered regarding it. This, however, is not the case, for recently it has been found that the comparatively little-known mesoxalic acid is formed in considerable quantity in the reaction, which in fact is the most convenient method of obtaining this somewhat rare compound.

Mesoxalic acid is easily recognised, being a ketonic acid and forming a well-characterised hydrazone with any aromatic hydrazine, and it can easily be isolated by taking advantage of the very sparing solubility in water of its sodium salt. About 10–12 grams of sodium mesoxalate are thus obtainable from 100 grams of cane sugar. Other carbohydrates such as dextrose, levulose, milk and malt sugars, and starch, also yield large quantities of mesoxalic acid when similarly violently oxidised by strong nitric acid.

# THE CULT OF THE TRILOBITES

By GRENVILLE A. J. COLE, D.Sc., F.R.S.,
*Professor of Geology in the College of Science for Ireland*

TRILOBITES, originally called trinuclei, are among the oldest extinct animals described from the British Isles. Edward Lhuyd (or Lhwyd) drew attention to them in 1699, in his work on the fossils under his care in the Ashmolean Museum, Oxford (*Lithophylacii Britannici Ichnographia*). To him, such forms were moulded picturesquely in the rocks, by some process of natural fertility ; their imperfections were due to their cramped surroundings, and it was impossible to believe that they ever were endowed with life. Even when organised fossils, as distinct from mineral fossils—that is, minerals dug out of the earth —became accepted as records of long-lost faunas and floras of the globe, each genus was regarded as an independent outcome of the Creative Mind, and the palæontologist was not encouraged to indulge in doctrines of descent. When, however, it became possible to trace out an evolutionary sequence, here yielding an orderly procession, here, *per saltum*, introducing a delightful element of surprise, the details of genera and species became far more than a dull matter of description. The succession of the trilobites became linked with that of the crabs and lobsters, or perhaps the insects, of our modern times, and the search for ancestral trilobites led to an inquiry into the origin of the arthropods as a whole.

The trilobites were generally recognised as crustaceans. They are unknown outside the Palæozoic, the " old life," era ; but that implies a long enough existence on the globe. In the earliest Cambrian strata a considerable variety of forms occurs, and one species is as much as six inches long. Other contemporaneous crustacea, the phyllocarids, were probably a shade higher in the scale of life ; but the trilobites surpassed them in abundance, dignity, and size. In the Cambrian seas they met with no more formidable rivals than carnivorous worms. Paradoxides of the British Middle Cambrian is often more than a foot (30 cm.) long. The trilobites were not adequately armed ; they probably went down quickly before the clawed and powerfully jawed eurypterids and the shark-like fishes of late Silurian and Devonian times ; but for long ages they were the dominant forms of marine life, and in those ages we have no trace of any superior creatures on the land.

While the general form for a well-conducted trilobite was a flattened ovoid, some of the Silurian genera show a fine exuberance of style. The Ordovician Æglina has a swollen head-bulge worthy of a scholar, while the Gotlandian Acidaspis bristles with spines, and Deiphon from the same system has narrowed down parts that are ordinarily in contact, until they stick out laterally as fantastic spikes. The Devonian trilobites show a far more sober tendency; the genera are reduced in number, and in Carboniferous times very few remain, descendants of early and unassuming forms. One genus, Anisopyge, survives into the Permian period.

Trilobites, then, attract by their quaintness and antiquity. Their carapaces are divisible into a head-shield, a body-portion (the *thorax*), and a tail-piece (the *pygidium*), and on these a three-lobed structure, running from front to back, may commonly be traced. On the head-shield there is a central bulge, the *glabella*, with a *cheek* on either side; the body-portion shows an axial bulge, with lateral extensions, the *pleuræ*, at a lower level on either side; the features of the thorax are carried on to the pygidium, and the axis is in many genera here prolonged into a spine. The body-portion is clearly divided into segments, from two to as many as forty-four, both these extremes occurring in genera from the Cambrian system. Some genera could roll themselves up, like woodlice, for comfort or protection. Both the head-shield and the pygidium commonly show traces of segmentation, as if they were originally or ancestrally flexible and had been modified by fusion of their parts. P. E. Raymond, however, in a stimulating paper which has been largely utilised in the present article, suggests that segmentation set in from an early condition when the carapace was continuous.

Till now, it has been usually supposed that the primitive form of the trilobites was segmented and worm-like, and showed little differentiation from one end to the other. H. M. Bernard, who devoted much thought to the matter, represented the ancestor as "a richly segmented annelidan" (*Quart. Journ. Geol. Soc.*, vol. 50, p. 430, 1894). When he worked on phyllopods under Huxley, discoveries of much importance were being made in America as to the structure of certain well-preserved specimens of trilobites, and of these he took full advantage (see also *ibid.*, vol. 51, p. 352).

From that time onwards, discovery in regard to trilobites has been mainly in the matter of appendages. When Hermann Burmeister wrote his treatise, *The Organisation of Trilobites, deduced from their Living Affinities*, for the Ray Society in 1846, he concluded (p. 44) that "the feet of trilobites were too soft and delicate to have left even their impressions." Linné in 1759 observed what he took to be antennæ in a specimen of the genus Parabolina; but these objects have been shown by C. E. Beecher (1896) to be portions of the anterior border of the head-shield. Had this apparent discovery by Linné been established, it would have saved a good deal of discussion as to whether trilobites were crustacea or arachnida, since the members of the latter class, which includes the heavily shielded king-crab, possess neither antennæ nor antennules.

In 1864 E. Billings, of the Geological Survey of Canada, brought to the notice of the Natural History Society of Montreal a specimen of *Asaphus platycephalus* (*Isotelus latus* Raymond), from Ordovician limestone, on the under side of which clear traces of limbs had been preserved. This was excellently figured in his paper published by the Geological Society of London in 1870, and Henry Woodward, in the discussion then aroused, suggested that the rarity of limbs in connection with the remains of trilobites might be due to the fact that the majority of the fossils were merely cast-off carapaces.

Six years later, C. D. Walcott, who is still indomitable in adding, month by month, to our knowledge of early forms of life, attacked the problem of appendages in trilobites by cutting thin translucent sections across rolled-up specimens of Calymene and Ceraurus. These came from the Trenton (Upper Ordovician) Limestone of the eastern United States; but the genus Calymene is familiar to British collectors, in a rolled up or extended condition, from the beautifully preserved specimens in the Gotlandian limestone of Dudley. Walcott cut slices of more than 2,000 individuals, and published his results in a memorable paper in 1881 ("The Trilobite: new and old evidence relating to its organisation," *Bull. Mus. Comp. Zoology, Cambridge, Mass.*, vol. 8). He was able to show that Calymene possessed 26 pairs of appendages, four being in the head-shield region, thirteen on the body or thorax, and nine on the pygidium. In addition, one slice gives evidence of the presence of antennules; but these are now much better known in other genera.

The long story of patient research now well rewarded is given us in detail by Prof. P. E. Raymond of Harvard University in the monograph already mentioned ("The Appendages, Anatomy, and Relationships of Trilobites," *Mem. Connecticut Acad. of Arts and Sciences*, vol. 7, Dec. 1920, price $6). He tells how in 1892 a bed of black shale, the Utica Shale, which follows on the Trenton Limestone in the Upper Ordovician series, was discovered at Rome, New York, crowded with trilobites of the genera Triarthrus, Cryptolithus, and Acidaspis. The structure of the fossils had been exquisitely preserved by replacement with pyrite (iron disulphide), and on thousands of these specimens

C. E. Beecher of Harvard set to work. He brushed or abraded away the shale from the hard mineralised fossils, which are only about an inch in length. He drew carefully the minute structure revealed, and, in a series of papers from 1893 to 1902 made known the appendages of trilobites almost as if the animals were alive.

Beecher's sudden death in 1904, while making a drawing of Cryptolithus, left to his pupil and successor P. E. Raymond the task of bringing together the latest results of his research, Raymond has now published much of the evidence for the first time, by means of a remarkable series of photographs, and by reconstructions made under his care by Elvira Wood. His descriptions lead up to a consideration of the origin and affinities of trilobites, which gives much room for thought, and, as the author will be the first to admit, much also for differences of view.

The appendages of trilobites include tactile organs, the antennules, which are almost straight in Ceraurus, delicately waved, yet perhaps rigid, in Triarthrus, and bent backwards in typical specimens of Cryptolithus. The other appendages, two to each body-segment, balancing one another on opposite sides of the axis, with others on the head-shield and pygidium, are of simple and almost uniform character. The type is "biramous," a jointed limb used for crawling and swimming having behind it—that is, inwards from the under surface of the animal—a limb bearing feathery rodlets or hairs; it seems certain that this inner limb was concerned with respiration. The five pairs of appendages attached behind the antennules on the head-shield have their inner ends notched for masticating food.

Raymond lays less stress than his predecessors on the browsing habits of trilobites, and gives them more credit for swimming than has hitherto been allowed. For him, the ancestor was a swimming arthropod of few segments. On the adoption of a crawling habit, an unsegmented shield was needed for protection of the upper surface of the animal. The increase in number of the appendages led to a breaking up of the carapace as activity developed, and the many-segmented forms, though existing as far back as the Cambrian period, have acquired a secondary character. It will be seen how widely this suggestion differs from that previously entertained. More important, perhaps, is the detailed comparison of trilobites with the modern phyllopods Branchipus and Apus, and the conclusion that these lie on a separate line, that they are less primitive than the trilobites, and that the latter represent the stock from which all other crustacea have diverged.

Raymond's considerable extension and revision of the fine work done by Beecher and by Walcott has been supplemented by a further publication on Neolenus by Walcott in 1921, and its author, whose first paper on trilobites appeared nearly forty years ago, now tells us that he proposes to reconsider these organisms when he has set his ideas in order " in the course of two or three years." Could anything represent more adequately devotion to the trilobitic cult ?

William Smith, when he laid down the principles of stratigraphical geology in the west of England during the strenuous Napoleonic years, urged that the succession of organic forms entombed in rocks had been designed to help the miner and the engineer. He would have been delighted to find how the successive genera of trilobites assist the classification of the most ancient fossiliferous rocks. The variety of structure in Lower Cambrian genera is amazing. These forms must have had ancestors, which were possibly soft all over and left no carapaces behind. *Beltina dani*, a crustacean appendage from pre-Cambrian strata in the Belt Series of Montana, has been referred by Walcott to the eurypterida, an arachnid race far higher then the trilobites, especially in the structure and localisation of their limbs. From Cambrian times to the close of the Gotlandian period trilobites can be employed as indicating successive zones. Their relative position in the sequence of strata in the field had to be first determined ; no purely zoological inferences must be allowed to dominate discussion. I have elsewhere related the somewhat humorous reversal of opinions as to " primitive " characters in trilobite genera, when the true position of the Olenellus-beds of North America was established (" The Story of Olenellus," *Natural Science*, vol. 1, p. 340, 1892). The result of exploration was to give immense importance to a genus previously obscure, and Olenellus and its associates, the Olenellus-fauna, now mark the Lower Cambrian beds throughout the world. Anything below the Olenellus-beds must be pre-Cambrian ; in Britain, the Longmynd range of the Welsh border, once held to be Cambrian, and the " Dalradian Series " of the Scottish highlands, long regarded as Ordovician, have, through the occurrence of Olenellus in overlying zones, been assigned to this dignified antiquity.

The Middle Cambrian has been marked in North America by Olenoides and in Britain by Paradoxides, which is probably the largest of the trilobites. The zone-trilobite of the American Upper Cambrian is Dicellocephalus, a genus with a spade-like expansion in front of the glabella. Dicellocephalus is also well known in Europe ; but the typical Upper Cambrian tribolite on this side of the Atlantic is Olenus. Enough has been said, perhaps, to explain a growing cult among palæontologists. Those who are not specialists will find an excellent and illustrated account of early crustaceans in *An Introduction to Palæontology*, by A. Morley Davies (Murby & Co., 1920), whose fifth chapter is devoted to "The Trilobite and other Arthropoda."

# TIME-RELATIONS IN AMPHIBIAN METAMORPHOSIS, WITH SOME GENERAL CONSIDERATIONS

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THERE have been three periods in the study of Amphibian metamorphosis. In the first, workers were concerned mainly with the morphology of the process, and the few experimentalists who, like Barfurth (3), attacked the problem did not arrive at far-reaching or conclusive results.

The second period we may term that of qualitative experimental study. It was initiated by the discovery of Gudernatsch (12) in 1911 that a diet of thyroid induced precocious metamorphosis in frog-tadpoles. This is now merging into a third, also experimental, but aiming at quantitative results.

It is the main purpose of this paper to draw attention to the problems in this quantitative method of attack; but before doing so it will be necessary to run over, with the utmost brevity, the chief facts elicited in the second period (32). Thyroid substance, then, whether given fresh or dried, or in the form of its active principle thyroxin, metamorphoses all Amphibia, with the exception of the Perennibranchiates, of which Proteus and Necturus, the only forms so far tried (16, 29), are insusceptible to the largest doses. Conversely, thyroidectomy totally prevents metamorphosis.

Inorganic iodine causes the metamorphosis of anuran tadpoles, but not of some at least of the Urodela (Amblystoma of various species, including the Axolotl). It will metamorphose even thyroidless anuran larvæ, as Swingle has shown (28), thus proving that the thyroid function is a specialisation of a function of normal tissues; but the same dose takes longer to metamorphose thyroidless than normal tadpoles, and there exists a threshold-concentration below which acceleration of metamorphosis may still be observed in normals, but no metamorphosis is produced in thyroidless specimens.

Abelin (1) has shown that tyramin and related substances also exert a metamorphic effect which is very much more marked when the substances are iodised. It has been thought by some workers (17) that these results with iodine and iodised amino-acids indicate that the metamorphic effect of thyroid is entirely related to its contained iodine, in contradistinction to the well-known effect which it exerts in mammals upon the basal metabolic rate. This, however, as later work shows, is a quite gratuitous assumption; the results in question are most simply explained if we assume: (1) that iodine is normally a limiting factor in the growth of the larval amphibian thyroid, (2) that both iodine and various amino-acids are "Bausteine" of the true thyroid hormone, (3) that some or all of the normal tissue-cells are also capable of elaborating thyroxin (or a very similar active substance) but that the thyroid cells perform this function in a much more specialised and efficient way. In addition, as regards these results, it is a fact which is often not taken into account by those accustomed to adult mammalian physiology, that the conditions during development are very different from those obtaining during adult life, particularly as regards regulation. Although external conditions, such as temperature, do exert some effect upon the size and activity of the tadpole's thyroid, yet, when iodine, etc., is given there is no shutting down of the manufacture of thyroid substance as occurs in adults, but the development of the thyroid, other conditions remaining the same, is independent of the rest of the body, dependent only on the amount of "Bausteine" it receives. Thus any proportion between (*a*) amount of thyroid hormone and (*b*) body-size and development may exist in larval life, up to that concentration of hormone needed to determine metamorphosis; the actual proportion found is dependent upon the treatment of the animal, the food it receives, etc.

The thyroid, however, is not the only gland concerned in metamorphosis. The pituitary is also of importance, although it is undoubtedly secondary to the thyroid (22, 23, 29). Tadpoles from which the anterior lobe of the pituitary has been removed also fail to metamorphose, while those into which it has been engrafted show an acceleration of metamorphosis. In anuran tadpoles this metamorphic effect of the pituitary is exerted, at least in greater part, via the thyroid. The thyroid of pituitariless specimens is markedly underdeveloped, but becomes normal if pituitary is engrafted. That the pituitary may, however, exert a true metamorphic effect independently of the thyroid is shown by the recent researches of Hogben, who has succeeded in metamorphosing not only normal but also thyroidectomised Axolotls by means of pre-pituitary injections. However, it appears that a much heavier dose is needed to accomplish the result with pituitary than with thyroid—as would indeed be expected from a knowledge of the effects of presumed hyper-function of the two glands upon the basal metabolism in clinical cases.

Other endocrine glands and tissues of various sorts have so far been found to be without effect. The retarding effect of thymus diet upon metamorphosis is not always elicited, and is probably, as Uhlenhuth has shown, due solely to a deficiency of some substance in the organ. The prostate has been stated to be active, but attempts at repetition have met with failure, or have at best produced slight changes in one or two organs only (15). Many other substances have been tried—muscle, corpus luteum, pineal, liver, gonad, and so on and so forth, some as food and some as injection, but so far without effect.

The net result of this qualitative study has been to show that metamorphosis is normally brought about by the secretion of two of the endocrine glands, the thyroid and the pituitary, and of these the thyroid is quantitatively by far the more important.

With these prolegomena, we can embark upon our main quest. Metamorphosis is caused by thyroid and pituitary. But what causes these to act at one particular moment rather than at another? Why is it that the common frog normally takes nearly the whole summer to metamorphose, while the American toad is ready in half the time, and the bull-frog spends three seasons in the larval condition? Why does the Axolotl normally never metamorphose, in spite of being the possessor of a thyroid which, when grafted into a frog-tadpole, will cause precocious metamorphosis? Why will no amount of combined thyroid and pituitary treatment cause the perennibranchiate Necturus to transform, while even this species is shown by grafting experiments (29) to possess a physiologically active thyroid?

Let us for the moment simplify the problem by considering only the thyroid. The question is then seen to resolve itself into one of time-relations—the time required for the thyroid to develop to a certain stage relative to the rest of the body. The relative nature of the process, the fact that the thyroid is in balance with other tissues, is well shown by various facts concerning geographical races of frogs on the one hand, and the effects of temperature on the other. Adler, for instance (2), took three lots of eggs of the same species of frogs, one from the Adriatic, one from the plains of Germany, and one from the high Alps, and let them all develop at the same temperature. The Alpine larvæ metamorphosed first, those from the Adriatic last; and the difference in metamorphosis-time was found to be reflected in the relative sizes of their thyroids, those of the Alpine tadpoles being the largest. Thus we may say that the inherited developmental rate of the thyroid appears here to be adaptively connected with environment, a larger thyroid being found where it is advantageous to counteract the retarding effects of low temperature. That this view is in all probability correct is shown by experiments on the direct effect of temperature on development and metamorphosis. If a single egg-batch is divided into several portions, and these kept at various temperatures, it is found that the larvæ at low temperature grow to a considerably larger size before metamorphosing. Witschi in a recent paper (33) has shown that this runs parallel with a differential effect of temperature upon the two antagonistic sides of the metabolic cycle. Tadpoles kept at low temperatures are plump and well nourished, with large livers well stocked with glycogen ; those kept at high temperatures are thinner, with few reserves. On the other hand, Adler (2) has shown in similar experiments that low temperature induces a large, high temperature a small, larval thyroid, this being a somatic effect as opposed to the genetic difference previously mentioned. Thus the differential effect of temperature upon metabolism is exerted against the thyroid, so to speak. In spite of the thyroid's well-known effect in increasing basal metabolism by increasing catabolic processes, the large-thyroided tadpoles at the low temperatures have anabolic processes in excess. This can only mean that the thyroid acts as a regulator of metabolism in these cold-blooded larvæ as well as in adult mammals, and, just as in mammals, undergoes functional hypertrophy when an extra demand is made upon it, and shuts down when not needed. This possibly has a bearing on the curious fact that while basal metabolism of women, even when corrected for size, is lower than that of men (24), their thyroids are slightly larger (19). This is perhaps a compensatory effect, which, however (as in the low-temperature tadpoles), is not fully adequate to make up for the lower metabolism of the female.

The low-temperature tadpoles show clearly that it is not the *absolute* size of the thyroid which determines metamorphosis, since in them metamorphosis does not occur until the animal has grown to a size above that normally attained by tadpoles, although the thyroid is above the average in size (and apparently in activity, since the histological picture is not abnormal).

The importance of the tissues in this partnership is well shown by the histological work of Champy (6), who, in tadpoles made to transform by a single meal of thyroid, investigated the " mitotic coefficient," or number of mitoses per thousand cells, of a number of tissues. He found that in some organs, such as the limbs, the coefficient was accelerated—*i.e.* increased at a regular rate until metamorphosis. In others, such as the gills or fin, it was retarded, and degeneration finally set in; while in still others, such as certain portions of the skin, no change was observed. Even in one and the same tissue, the most diverse conditions might obtain; thus in the ectoderm of the head and stomodeum, some regions were unaffected, others were found to respond by increased growth, others by degeneration, although all three were previously indistinguishable histologically. In other words, different tissues are differently *sensitised* to the thyroid hormone, the optimum concentration of thyroid being low for some and high

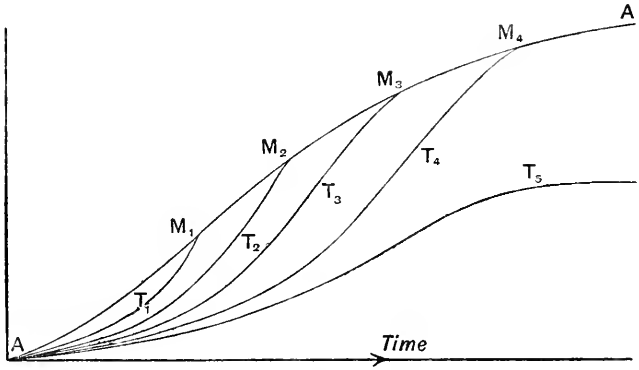



FIG. 1.

A A. Growth of larva, reduced to common scale.
$T_1$–$T_5$. Curves of thyroid growth (thyroxin concentration) in examples $A_{1-5}$.
$M_1$–$M_4$. Points at which metamorphosis occurs.

for others, while still others are not affected by considerable changes.

Thus the most varied combinations of tissues and thyroid are possible. In passing, we may note that the fact that the limbs of Anura are accelerated in their development by thyroid while those of Urodela are not, implies that those of Anura have become sensitised to thyroid concentration late in phylogeny; the tail of Anura has also become sensitised at a late evolutionary period, but to degeneration instead of to increased activity. For the present, however, we may neglect these variations in separate organs, and focus our attention on the metamorphic change as a whole. This, as I have elsewhere indicated, implies (1) the existence of certain tissues, such as the fin and gills, which have a low optimum metabolic rate, and degenerate if the thyroid concentration is raised above a certain point, (2) the existence of other tissues, such as the limbs, which have a high optimum, and increase their rate of development as the thyroid concentration increases. Then we have the following chief possibilities to consider: (A) (fig. 1)[1] Relative rate of thyroid development variable. (1) Very rapid development of the thyroid; early metamorphosis at a small size: e.g. *Bufo lentiginosus*. (2) Moderately rapid development of thyroid; metamorphosis in late summer: *Rana temporaria, R. tigrina*. (3) Slow thyroid development; metamorphosis only in the second season: *R. clamitans*. (4) Very slow thyroid development, metamorphosis in the third season, at a very large size. *Rana catesbeiana* (American bull-frog). (5) Thyroid's maximum size below that needed for a thyroxin concentration capable of including metamorphosis. Probably Typhlomolge, one of the Perennibranchiates. (6) Thyroid absent, as in thyroid-

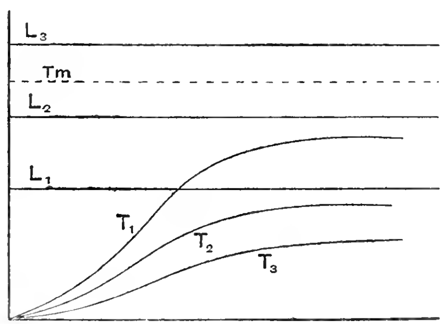



FIG. 2.

$T_1$–$T_3$, curves of thyroid growth, and $L_1$–$L_3$, levels of larval tissue, susceptibility to thyroid, for normal Urodele, Axolotl, and Perennibranchiate respectively. $T_m$, maximum concentration of thyroid to be produced in the body.

ectomised tadpoles. Total absence of metamorphosis; growth to a very large size.

(B) (fig. 2) Thyroid developmental rate and maximum remaining approximately constant. (1) Tissues highly sensitive; probably Anura. (2) Tissues sensitive: probably most Urodela. (3) Sensitiveness of tissues below threshold values needed to bring about metamorphosis. Probably Necturus.

(C) Both thyroid and tissue sensitiveness varying; *e.g.* in the Axolotl probably the tissue sensitiveness is reduced, as is also the rate of thyroid development and the maximum concentration attained by its hormone.

It is obvious that such a scheme is provisional and tentative only, especially as regards the particular examples given; but

[1] The figures are intended only as graphic symbols, not as representing actual quantitative relations.

it is also, I think, obvious that the classification adopted is in broad outlines correct.

The Axolotl is of peculiar interest. As is well known, this animal is normally neotenous—*i.e.* never metamorphoses, but becomes sexually mature in the larval form. Cases of spontaneous metamorphosis do, however, occur. It is not generally known, however, that there are two geographical races of the species which differ markedly on that point. The variety from the non-mountainous part of the United States (New Mexico) is very prone to spontaneous metamorphosis, so much so indeed that Dr. Swingle writes to me that he considers it almost useless for experimental work on metamorphosis. In the specimens from the Rocky Mountains and the highlands of

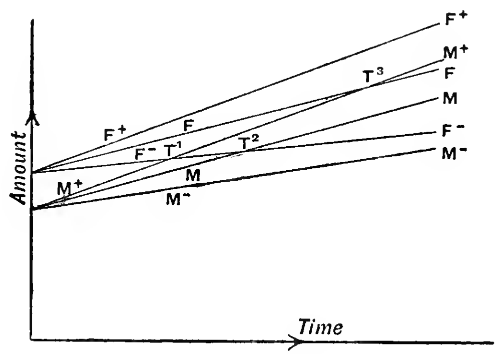



Fig. 3.

$F^+$, F, $F^-$. Curves of production of female-determining substance in various strains of Lymantria.

$M+$, M, $M^-$. Corresponding curves for male-determining substance.

$T^1$–$T^3$. Points where sex-development is transformed from female to male; occurring in crosses of $F^-$ ♀ × $M^+$ ♂, $F^-$ ♀ × M ♂ and F ♀ × $M^+$ ♂ respectively.

Old Mexico, however, spontaneous metamorphosis is exceedingly rare. That it does occur is well established; indeed the knowledge that the Axolotl is not a Perennibranchiate, but a neotenous larva of a species of Amblystoma, was due to such a case occurring under Dumeril's eyes in 1863 (8). But it has always been very uncommon, and in the strains now bred by aquarium dealers in Europe appears to be practically non-existent. This fact is very probably correlated with the fact that the old Mexican race inhabits large permanent lakes and mountain streams; while that from New Mexico lives mainly in small pools liable to dry up in summer. Be that as it may, the mountain race is of great experimental importance, as it provides an "all-or-nothing" metamorphic reaction.

The Axolotl's thyroid is not markedly small for its body size, and is still, as grafting experiments show, capable of inducing metamorphosis in tadpoles. It has been supposed that its failure to cause metamorphosis normally is due to its possessing only a storage function, and not liberating its secretion into the blood; but this appears to be negatived by experiments now being conducted by Hogben and myself. Although grafting a thyroid from one individual to another appears always to bring about the liberation of all or most of the secretion, yet grafting of the thyroid of one, two, or three animals into a single other specimen has been without effect on metamorphosis. It thus seems probable that although the thyroid is almost certainly reduced in rate of development and efficiency, yet it is largely a decrease in the sensitiveness of the tissues to thyroid that has brought about the normal failure to metamorphose in this animal.

The pituitary, of course, constitutes a third independent variable. If it has a rapid rate of development, it will tend to bring about early metamorphosis, partly on account of its own direct effect, mainly by exerting an effect upon the development of the thyroid; conversely, slow pituitary development will, *ceteris paribus*, bring about a delay in metamorphosis. It is quite possible that other ductless glands may play an opposing rôle—the islets of Langerhans, for instance, to whose action on carbohydrate metabolism the thyroid appears to be antagonistic. For the present we must be content to lump such possible specific effects together under the head of "the rest of the body." But it can be regarded as established that the chief positive effects on metamorphosis are exerted by the thyroid.

From what we have said it appears clear (1) that the rate of development of the thyroid, and its maximum size, can vary genetically. This is shown positively in the three geographical races of one species investigated by Adler; and is the only reasonable hypothesis of the variation of time and size of metamorphosis as seen, for instance, between a bullfrog and an ordinary frog. (2) That the effectiveness of the thyroid depends not on its absolute, but upon its relative size or developmental rate; and that the sensitiveness, etc., of the tissues to which it is relative can also vary genetically (Champy). (3) That both thyroid and condition of tissues can be affected by environmental influences, *e.g.* temperature, or, in the case of thyroid development, by the quantity of certain substances (such as iodine) present in the food. (4) That when thyroid concentration (or it would probably be more accurate to say its result—basal metabolic rate) reaches a certain relative level, metamorphosis is initiated by the breakdown of those tissues which are adapted only to a lower rate of metabolism. The final result of the quantitative interaction of the thyroid and the other tissues is thus a qualitative, sharply marked response, an end-point.

It remains to indicate other fields in which similar reactions between developmental processes occur. The best worked out is that of sex-determination. The Morgan school, and Bridges in particular (4), have definitively shown that in Drosophila sex-determination is an affair of balance. The X or sex-chromosome is predominantly female-determining, the rest of the chromosomes, and especially the small or so-called fourth chromosome, predominantly male-determining. Males, females, ultra-males, ultra-females, intersexes inclining either to maleness or to femaleness, all can come into existence as a result of different numerical relations of the chromosomes and consequent altered equilibrium of genetic factors concerned with sex.

A still more striking parallel is afforded by Goldschmidt's intersexual moths (11). Certain crosses between the Japanese and European races of Lymantria produce *developmental intersexes, i.e.* individuals which start as one sex, and after a certain moment change over and continue as the other. By employing different sub-races, the time at which the change occurs is altered, genetic females being in certain crosses all converted into somatically normal males. These phenomena appear to depend upon differences in rate of production of male- and female-determining substances (see fig. 3). We are thus justified in speaking of a sex-metamorphosis in these abnormal individuals and also in protandric or protogynous hermaphrodites, and in comparing the mechanism at work to that operating in Amphibian metamorphosis. A rich field is opened up for investigation into the external agencies which influence the time of this sex-metamorphosis.

Many similar phenomena can be found in the development of higher forms, although here the conditions are more complex, our knowledge less complete. In the first place, the mammal, unlike the tadpole, grows best at a high thyroid concentration. This is well illustrated by Sutherland Simpson's lambs, which were thyroidectomised shortly after birth, and grew very slowly. In sheep, the psychoneural faculties are little affected by absence of thyroid ; but in man, congenital absence of the thyroid gives rise to cretinism, in which not only is growth stunted, but the brain and mind fail to develop. Addition of thyroid to the diet often cures the condition. Thus the mammalian organisation needs for its development not only a high uniform temperature, but a high uniform thyroid concentration, and this is more particularly true of the human brain. In the frog-tadpole, on the contrary, thyroidectomy allows normal growth of every part ;

it is only the change to frog-organisation that does not occur. In this condition, the statement that the relative size of the thyroid progressively increases as we ascend the vertebrate scale, is of considerable interest. In a perfectly sober sense, the mammal is being continuously drugged (by itself), continuously stimulated to reach a higher level of metabolism than would otherwise be possible, but one which is necessary if the complexity of its organisation is to develop properly.

In this case we are dealing with balance of glands and tissues, and tissue-sensitisation. Of actual time-relations in development perhaps the most striking example is afforded by the phenomena of puberty, in which again we have an all-or-nothing reaction—the formation of mature gametes, and the full development of secondary sexual characters. It is clear, after the experiments of Steinach (25, 26), Sand (21), Lipschütz (18), and others, that the gonads in some real sense determine secondary sexual characters: further, Minoura's work (20) has shown that in the fowl, the gonad is producing the same hormonic substance in the embryo, in the chick and in the mature bird, although, in one case, it is determining the accessory sexual apparatus, in the next growth as well, in the last, secondary sexual characters in addition. Why does the determination of full secondary sexual characters only occur at sexual maturity? and why does sexual maturity come when it does? Interesting unpublished work of Crew's indicates that in various mammals the function of the gonad in determining accessory sexual characters may be, as a not unfrequent abnormality, in abeyance during the pre-pubertal period, and yet puberty and the determination of full secondary sexual characters take place normally, and at the normal period. This would indicate that the gonad needs activation by different means (presumably by different endocrine organs), in the pre-pubertal and pubertal periods.

Again, it is often said that glands like the pituitary and suprarenal cortex exert an effect on the onset of puberty. So they certainly appear to do. But what causes them to exert this effect normally at a certain age, and not earlier or later? That they could exert this effect at other ages is shown by the precocious sexual development caused by tumours in the adrenal cortex (5), infantilism associated with pineal absence (34), or pituitary hypoplasia, and so forth. That environmental as well as genetic factors play a part is shown by the recent work of Steinach and Kammerer (27), who found that precocious maturity in the rat could be induced by high temperatures, and vice versa.

Obviously we have here a similar picture to that of amphibian metamorphosis, but certainly less well analysed, and almost certainly more complex. Different glands are developing at a different rate relative to each other and to the body as a whole; each may vary independently of the rest, and the end-result may be accelerated or retarded accordingly. In some rare cases we get a state of affairs essentially comparable, as a process, to neoteny—we get delay in differentiation pushed to such a pitch that maturity never occurs at all.

In the Loraine type of infantilism, the pituitary appears to be underdeveloped; but, whatever be the cause, full sex-differentiation remains absent for a number of years after the normal date of puberty. Ateleotic dwarfs are infantile in another way. They are not merely of small but of diminutive stature; the body as a whole is in many respects extremely infantile, while the sexual organs often mature with comparatively small delay. In other cases, however, the delay is considerable, while in one subtype maturity never occurs. This gradation from normal time-relation through delay to non-appearance is of great interest, as it indicates that there are steps in the process, that it is a case of originally balanced equilibrium tilted right over to one side, exactly as in neoteny (7, 9).

Finally we should mention the extraordinary but happily very rare phenomenon known since Hastings Gilford's work (9, 10) as *progeria*. In these cases, superimposed on an attempt at normal development, there is a precocious senility producing, if not a " greybeard of five," as in the *Bab Ballads*, at least a miniature very old man in under twenty years. Part of the mechanism which runs the body is out of gear, and is, it would seem, causing the cycle to be run through at excessive speed. In connection with this, we should remember that the cycle in different species does run at different rates. In the rat or mouse, for instance, the embryo at a given size is far more differentiated than a human embryo of the same age, and the phases of the cycle—infancy, adolescence, maturity, and old age—are flashed through at an increased *tempo*.

Undoubtedly, similar but much smaller differences in general *tempo* can exist in individuals or races of the same species, and these will probably give curious phenomena on crossing. Goldschmidt's intersexes in moths appear to owe their production to some such general differences in rates of differentiation. It is no use investigating only their qualitative effects. Various lines of evidence indicate—what the study of amphibian metamorphosis has shown definitely to be true in certain cases—that many of the ductless glands are true regulators, in that they simply modify the rate of processes which would take place anyhow. Mammalian metabolism continues in the absence of the thyroid—but it drops about 60 per cent. Some ossification occurs in the old Axolotl, but takes years to reach the same general degree which an overdose of thyroid will bring about in three weeks. Growth and differentiation occur in the limbs of thyroidless tadpoles, but at a rate perhaps 30 or 40 times less than in normal animals, and 300 or 400 times less than in thyroid-fed specimens.

It is useless to pursue the subject further in the present state of our ignorance; but I hope that I have said enough to show that, if real accuracy of experimentation is introduced into such a subject as that of amphibian metamorphosis, and if we accustom ourselves to thinking in terms of rates and equilibria and processes, we shall in a few years be able to lay the foundations of a branch of biology which will bring the same sort of view-point into the whole subject as was introduced into chemical science by the study of physical chemistry. We are now, thanks to the labours of the physiologists, learning to appreciate the delicacy of regulation in the adult; we shall then embark on the study of regulation in the developing organism.

## REFERENCES

(1) ABELIN, 1920. *Biochem. Ztsch.*, **102**, 58.
(2) ADLER, 1916. *Pflüger's Arch.*, **164**, 1.
(3) BARFURTH, 1887. *Arch. mikr. Anat*, **29**, 1.
(4) BRIDGES, 1921. *Science*, **54**, 252.
(5) BULLOCK and SEQUEIRA, 1905. *Trans. Path. Soc.*, **56**.
(6) CHAMPY, 1922. *Arch. Morph. Exp. et Gén.*, **1**, no. 4.
(7) CUSHING, 1912. *The Pituitary Body and its Disorders.* Philadelphia and London, 1912.
(8) DUMERIL, 1876. *Ann. Sci. Nat.*, (5) **7**.
(9) GILFORD, H., 1911. *The Disorders of Post-natal Growth and Development.* London, 1911.
(10) GILFORD, 1913. *Lancet*, 1913, 587 and 664.
(11) GOLDSCHMIDT, 1920. *Ztsch. ind. Abst. Vererb.*, **23**.
(12) GUDERNATSCH, 1912. *Arch. Entw. Mech.*, **35**, 457.
(13) HOGBEN, 1922. *Proc. Zool. Soc.*, 1922.
(14) HOSKINS, 1920. *Endocrin*, **4**, 1.
(15) HEGNER, 1922. *Am. J. Physiol.*, **61**, 298.
(16) HUXLEY and HOGBEN, 1922. *Proc. Roy. Soc.*, **93** (B), 36.
(17) KENDALL, 1919. *Am. J. Physiol.*, **49** (Proc.), 136.
(18) LIPSCHÜTZ, 1919. *Die Pubertatsdrüse und ihre Wirkungen*, 1919.
(19) M'CARRISON, 1917. *The Thyroid Gland*, London, 1917 (p. 29).
(20) MINOURA, 1921. *J. Exp. Zool.*, **33**, 1.
(21) SAND, 1921. *J. de Physiol. et Pathol. Gén.*, **19**, 305.
(22) SMITH, P. E., 1920. *Amer. Anat. Mem.*, no. 11.
(23) SMITH and SMITH, 1922. *Anat. Rec.* **23** (Proc.), 38.
(24) STARLING, 1920. *Principles of Human Physiology*, 3rd Ed., London, 1920 (p. 696).
(25) STEINACH, 1913. *Centralbl. f. Physiol.*, **27**, no. 14.
(26) STEINACH, 1920. *Arch. Entw. Mech.*, **46**, 12.
(27) STEINACH and KAMMERER, 1920. *Arch. Entw. Mech.*, **46**, 391.

(28) Swingle, 1919. *J. Exp. Zool.*, **27**, 397.
(29) Swingle, 1922. *Anat. Rec.*, **23** (Proc.), 41 and 100.
(30) Uhlenhuth, 1919a. *J. Gen. Physiol.*, **1**, 23.
(31) Uhlenhuth, 1919b. *Endocrin*, **3**, 285.
(32) Uhlenhuth, 1921. *Am. Nat.*, **55**, 193.
(33) Witschi, 1922. *Ztsch. Ind. Abst. Vererb.*, **29**, 31.
(34) Zandren, 1921. *Acta Med. Scandin.*, **54**, 323.

# POPULAR SCIENCE

## THE EVOLUTION OF THE CATERPILLAR

By HERBERT MACE, F.E.S.

### I

In most insect orders, the younger, or larval form, does not vary much from one simple type. The reason for this is quite clear and is, indeed, one of the strongest arguments for the theory that protective resemblance plays a profoundly important part in the outward appearance of animals and plants. Just as the roots of plants, which are underground and not exposed to the risk of discovery by animals which *look* for them, seldom vary far from the simple cylindrical form, without marked coloration, while the stem and leaves, which are subject to all the influences incident to exposure, vary infinitely: so the larvæ of insects, being, for the most part, hidden from view, would not benefit by an approximation in appearance to their surroundings. The larvæ of all the bees, living in prepared cells, are much alike. Those of the flies, which are generally deposited in a mass of readily assimilated food, differ only in the possession of slightly varying organs for extracting the nourishment. All these and those of many more orders which pass their lives in a dark retreat, are whitish or neutrally coloured.

The case of Lepidopterous larvæ is very different. In the majority of instances, they are destined to live amongst the leaves of plants of varying species, presenting the most intricate problems of concealment and safety for solution.

The basis of these problems is the same in all cases. Adequate nourishment must be procurable for the duration of the larval stage, which is the only one in which growth takes place, and the vigilant eyes of predatory animals, mostly birds and reptiles, must be eluded.

### II

As a first step towards the solution of this problem, the majority of caterpillars feed only at night, the number which are active in the daytime being extremely small, though a fairly large section, including the interesting hawkmoths, which form the subject of another paper (*Nineteenth Century*, Feb. 1921), are content to feed during the twilight of early morning and evening. These night feeders are thus able to rest during the daylight hours, and even if they remain exposed to view, the absence of any movement on their part affords a considerable measure of concealment, which is very much increased by approximation of form and colour to the surroundings. Feeding, as the majority do, upon the leaves of plants, it is only in accordance with what we should expect, that most caterpillars are green in colour. Of those which are not of this protective hue, many adopt a different and perhaps superior method of concealment. These belong to the great tribe *Noctuæ*, which comprises, for the most part, soberly coloured moths, which fly only at night.

Most of these caterpillars are of the same dirty white or yellow colour familiar in the case of purely subterranean larvæ, except that it is usually very much darker in shade or is broken up by dark bands or stripes, which are interesting as showing just how larvæ which are, as it were, breaking away from the restrictions imposed by an underground existence may most profitably vary to accord with new conditions.

These Noctuid larvæ pass the daytime buried in the ground, under stones, the loose bark of trees, or in the debris which surrounds the base of established plants. They very rarely remain on the leaves during the hours of sunshine, but shun daylight and only creep forth when darkness has fallen.

Small though it may be, there is, however, a certain amount of risk run, even by night. There are a few enemies, bats, frogs, mice, and predatory insects of other orders, which hunt at night, and their senses are naturally adapted to the hours of gloom, which, though called dark, are not by any means entirely free from light. On a normal summer night a white object is distinctly discernible, even by the ill-adapted human eye, and it is manifest that the white colour of purely subterranean larvæ would be most unsuitable for night-rambling in the open. Hence the general darkening in colour, or, what is perhaps more significant, tendency to the non-actinic yellow shades noticeable in this great group, while the frequent appearance of stripes and bars is now well recognised as one of the most perfect means of concealing the outline of an object. As everyone knows, it was employed during the great war to disguise shipping, and proved very effective.

One may therefore dismiss, as of no specialised interest, the species of moth-larvæ which live underground, feeding on the roots of plants or venturing out only in the night-time;

but they are interesting because they show that, however far up the scale of progressive development the perfect insects have risen, so long as the larvæ live in surroundings which are not subject to the influences of light, their outward appearance does not change to any extent.

Before passing on to consider the very varied forms which come into the open, a departure which is comparatively unusual in the Order, but leads very naturally from the subterranean habit, may be given some attention. This is the case of the wood-boring and leaf-mining species. The purpose of concealment has, in this case, not been satisfied by approximation of colour, and most of the leaf-mining species are of whitish or indefinite coloration. They are, from the very nature of the case, exceedingly minute, and the perfect moths are seldom more than one-eighth to a quarter of an inch across the wings. They are, however, exceedingly beautiful, and under the microscope are seen to have elaborately patterned scales, often of rich metallic colours, gold and silver being particularly predominant. The method of these tiny caterpillars is to consume only the inner substance of the leaf, so that the tougher outer coats, above and below, remain unbroken, and the result of their operations is a pale marking, commencing as a fine line, which wanders erratically about the leaf and grows, like a river, as the miner increases in size.

There is an incredibly large number of these minute moths, the British species alone being approximately 200 to 300, and practically all our commoner plants have one or more species of miner devoted to them. Those who are interested in this pigmy race, may study them readily enough by collecting the mined leaves and preserving them in a jar (covered with a sheet of glass) until the winged insects appear.

## III

The wood-borers are comparatively few in number and in this country are confined to the families *Sesideæ*, *Zeuzeridæ*, and *Cossidæ*. Of the first family there are about a dozen British species, all of which are remarkable for the fact that their wings have very few scales upon them—they have a striking resemblance to wasps, bees, and insects of other orders. That they have diverged from the common ancestral stock to a much less degree than the majority of Lepidoptera, is perfectly obvious from their general appearance, and the fact that their larvæ are naked and whitish in colour and thus conform more closely to the primitive type of grub, is additional evidence. In fact, when the whole of the circumstances of this group are studied, it seems passing strange that the earlier systematists persisted in placing them in the same tribe as the much more specialised Hawkmoths. These "Clearwing" grubs live in the interior of numerous species of plants: poplars, alders, currants, and even smaller plants, such as the sea-thrift and bird's-foot trefoil, having species attached to them. In many cases the part of the plant occupied is the root, and the large and handsome "Hornet Clearwings" can generally be captured in the districts they inhabit, by watching for their appearance at the base of poplar trunks. On the other hand, the Currant Clearwing, which is no mean foe to this plant in some places, inhabits the upper part of the stem.

Of the other two families, the Wood Leopard Moth, the Reed Moth, and the Goat Moth, are the only British representatives, but they exhibit the highest development of the wood-boring habit in the Order, the larvæ being highly specialised for their existence. Their general form is cylindrical, without the tapering at both ends which is found in most caterpillars, and the divisions between the segments are very strongly marked. Except for a few scattered hairs, they are naked, and to assist in moving through their burrows, the fleshy prolegs, sometimes called "claspers," are coronated, while the head is rather flattened and the jaws are particularly strong.

In the perfect form, however, all these insects are typically lepidopterous, being well clothed with scales, and, except for the rather unusual length of the abdomen, show no undue deviation from normal families. The Reed Moth, as its name implies, lives in the interior of reeds. It is yellowish, with a brown back and head. The Wood Leopard, so called because both moth and larva are very much spotted, is devoted to more substantial matter, feeding on the wood of various trees, of which apple, willow, mountain ash and, some say, even elm, are examples. Generally speaking, the softer woods, particularly willow, are preferred by this insect; but, in any case, its borings are very extensive, and, when the larva is full grown, quite a quarter of an inch in diameter. Its colour is bright yellow, with deep black spots or warts, and it is two years in coming to maturity.

The most striking and formidable of the group is the Goat Moth, or *Cossus*, on account of its great size, the length of its life—it takes three or four seasons to reach maturity—and the serious damage it inflicts on timber. The moth itself is dark brown, very stout-bodied, and expands from 3 to 4 inches. It appears about June, and the females deposit their eggs in cracks in the bark of various trees, the hardness of the wood being no bar to attack. I have found the insect frequently in poplars, but quite as commonly in oaks. When very young the caterpillars content themselves with the comparatively soft tissue beneath the bark, but gradually extend their operations—there being generally a pretty extensive colony in each tree—until the whole of the ligneous portion is honeycombed with their burrows. In advanced stages, borings often come closer to the surface and sap exudes freely, this being mixed with an excretion from the caterpillars, which gives it a most peculiar odour, said to resemble that of he-goats (whence the name) but to my mind quite distinctive and only slightly similar. In any case, it is very powerful, and I have generally located goat-ridden trees by perceiving this odour—often a considerable distance away.

The goat caterpillar shows a striking departure from other borers in its colour, which is dull flesh, the back being dark red, almost mahogany-like in colour. It seems reasonable to suppose that this is associated with its choice of tree, for it is not very different from that of the wood of many oaks, and the larvæ are not easily seen among the debris if they remain still. It need scarcely be pointed out that these and other wood-boring insects are liable to fall a prey to birds—woodpeckers, for example—and it is manifest that even a slight resemblance to the wood must afford a measure of protection.

Many well-accredited stories of the power of the Goat Caterpillar's jaws have been told. In one case, a collector placed a number in a cigar-box, which he stood on the piano. During the night, one gnawed through box and piano and was found wandering in the interior the next morning. An even more remarkable case has the unimpeachable authority of the late Prof. Henslow. He says: "I placed half a dozen caterpillars of the goat-moth in a glass jar, with sawdust and a piece of willow, and covered the mouth with sheet lead, which was perforated with an awl to admit the air. Three of the caterpillars were found crawling on the floor, and on examining the jar I found they had effected their escape by gnawing the lead, having enlarged two of the perforations sufficiently to enable them to pass out of their prison."

## IV

The Goat Moth, widely though it differs in size, is linked with another interesting group of caterpillars, which have contrived to evade the risks of feeding in the open in an exceedingly ingenious way, by the familiar Codlin Moth, a small species whose larva is only too frequently found in the interior of apples and is, therefore, a true borer. The great mass of the Tortrices, to which tribe this belongs, are distinguished by their habit of rolling the leaves of the plants on which they feed, in order that they may pursue their meals under cover. The adoption of this very specialised procedure is rendered possible by the secretion, at a much earlier stage of life than is usual in the Order, of the familiar silk which forms so frequent a covering to the pupæ of moths. From its earliest days, the Leaf Roller makes use of this material for the purposes of its work. In some cases the leaves are rolled from end to end, in others, two leaves are attached together, while in some the opposite sides are drawn towards each other. In either case, the operation is performed by attaching a line of silk to the two points to be brought into contact and repeatedly shortening them, so that they are drawn together.[1] In the most perfect leaf-rolling, the tip of the leaf having been thus drawn up to the standing part, another line is attached to the outside of the roll and this shortened in like manner, the operation being repeated until the whole leaf is rolled up tightly, like a carpet. It is obvious that in this case there are several layers of leaf which can be consumed without the caterpillar exposing itself. Even so, these insects are not entirely safe from enemies. The ends of the roll are open and are not only entered by predatory insects, but even small birds can sometimes extract the occupant. These larvæ are, therefore, in many cases able to make use of their silk in another manner. Should an enemy enter one end of the roll, the caterpillar attaches a line to the leaf and slips out at the opposite end, falling into midair, where it hangs out of reach of its enemy till the latter has departed. These Tortrix larvæ are able to move backward almost as readily as forward.

## V

It is notable that in this group, in which most species are of indeterminate greyish colour, there is a distinct tendency for green coloration to appear. During a part of its life, as when it is engaged on the construction of its roll, the caterpillar is exposed, and any tendency to green colouring is bound to assist in hiding it from its vigilant foes. The advance of the race, thenceforward, seems to be more directly connected with the adaptation of colour to environment. The advantage of protective coloration is that it affords automatic protection without the necessity for conscious effort on the part of the individual, such as is represented by wood-boring and the construction of a special habitation like these rolls. As protective coloration acts most effectively when there is

[1] It is probably natural shrinkage of the silk, as it dries on exposure, which draws the parts together.

least activity, it is bound to be a more potent influence than any method which entails activity. In the Geometers, or Loopers, by far the larger number of individuals, if not of species, are green in colour. Pure green is not the most effective disguise, however, even though the particular shade harmonises exactly with that of the leaf, for every leaf is more or less marked with streaks of lighter colour, caused by the natural venation. It is quite in accord with this, therefore, that the majority of caterpillars have stripes, either running lengthwise of their bodies, or transversely across them. Most often these streaks are whitish or yellowish, but others are of darker shades of green, black, or brown.

Perhaps no greater degree of perfection in this direction has been reached than in the case of the common Winter Moth, a Geometer found in profusion on almost every kind of British fruit and forest tree. In spite of the fact that this insect forms probably the chief food of numerous small birds, it maintains its position as the most abundant of tree-feeding caterpillars, and its protective coloration is, subject to modification in opposite directions, of lighter or darker colour and marking, exactly that which theoretically affords the best disguise.

While emancipated from the necessity of making rolls, the Geometers do, in many cases, retain the power of silk spinning during their larval period and make use of this material as a safety line in the same way as their leaf-rolling cousins.

There is in this group the beginning of a further development of the exterior appearance which, so far as can be understood at present, is solely connected with protective resemblance. This is the appearance of humps, warts, and similar protuberances in irregular positions on the body. The connection between these humps and protective resemblance does, it must be confessed, seem rather remote in some cases, but the well-marked instances where it is known to serve that purpose, lend colour to the general theory that this is the sole object served by them. These protuberances may be present on one or more segments of the body, but in the same species they are always in one place, sometimes being located on the back and sometimes on the sides. The general idea concerning them is that anything which tends to break the regularity of outline tends towards concealment, by making the object blend more naturally into its surroundings. The strongest evidence of this is found among certain Geometers which have the habit, when resting, of stretching out their bodies stiffly, attaching themselves by the anal feet, in which position they resemble small twigs and in some cases may easily be overlooked on this account. Indeed, in the case of the Thorn

Moths, which are at once notable for the prominence of their warts and the facility with which they assume the twig-like aspect, the resemblance is astounding.

Concurrently, there appears a tendency for the colour of these insects to vary from the green of the majority, many of such caterpillars being of brown or yellow shades, all more or less approximating to the general hue of twigs. These caterpillars are able to maintain the rigid attitude for hours and nothing induces them to relax themselves. One instance, that of the Scalloped Hazel Moth, is worthy of special mention, for this caterpillar adds to the deception, or so it may be assumed, by deliberately quivering in a very rapid and remarkable manner.

## VI

In a group of rather loosely allied species, among which are some striking insects, such as the familiar "Puss," the "Lobster," and the "Hook-tips," the development of warts and humps has reached a specialised development which in several cases modifies out of all recognition the normal cylindrical caterpillar form, and it seems more than likely that this extreme variation is beneficial by giving the insect a resemblance to some other object which is either useless as food to its natural enemies or positively harmful. Superficially examined, nothing could be less caterpillar-like than the Lobster larva, with its humped segments—appearing like a row of teeth—its extremely long, jointed legs, and above all, its extraordinarily enlarged anal segment, which being held up at right angles to the rest of the body, suggests that this is the head, instead of the tail, of the creature.

An even more significant and striking character of this caterpillar is the pair of fine filaments projecting from this erected anal segment. It appears to be the simplest development of a not merely protective, but quite offensive weapon, for although it appears in this case to be comparatively innocuous, it attains considerably more important development in the related Puss. The anal segment of the Puss caterpillar is forked, each branch tapering to a truncated tip and forming a sheath for bright red filaments, which can be protruded to a considerable distance. When the insect is alarmed, it waves the filaments in the air very vigorously. The Puss has another specialised offensive weapon in the power to eject strong acid from the first thoracic segment, on the underside, the discharge often being thrown to a considerable distance.

In modified ways, all the devices hitherto reviewed reappear in the more highly developed section of the Lepidoptera known as butterflies, but in the higher groups of moths, quite different, although analogous lines of development have been followed. The most general is the growth of hair over the caterpillar's entire body, a feature which marks one enormous group as occupying a position of its own. Many among the less specialised families have a certain amount of hair. Indeed, it is the exception for a caterpillar to be entirely naked, but in most cases the hairs are short and thinly scattered and scarcely count in the general struggle for protection against enemies. In the Bombyces, however, the hair is more or less closely packed and often of considerable length. The caterpillar of the Garden Tiger Moth, commonly known as "woolly bear," on account of its long silky coat, is a striking example. Hairiness seems to be an extremely sure protection, not by disguising the creature, but by rendering it distasteful to the majority of its avian enemies. The calm fashion in which a woolly bear will march about the naked ground in broad daylight seems to indicate such a strong sense of security as to have eliminated completely the instinct to conceal itself. In the Ermine and Brown Tail caterpillars, which display themselves openly on the bushes, the same evidence of protection is afforded, though, in most cases, at least partial seclusion is sought during the daylight hours.

The peculiarities of the Hawk Moth caterpillars have been dealt with in detail elsewhere. They are, however, of the customary cylindrical form, but in the Elephant Hawks, the singularly swollen segments behind the head, which conceal the head at will, and the remarkable eyespots which adorn the sides and give the creature an air of alertness, even while it is asleep, seem sure evidence of development on protective lines, as do the oblique stripes which almost universally adorn the sides of the bodies of members of the group. The horn on the tail, so mysterious a feature of this group, may be a relic of the singular appendage of the Puss, or may, in ancestral forms, have aided concealment by its resemblance to a thorn or prickle.

## VII

As I have hinted, in the most exalted group of this order, the butterflies, every type of caterpillar seems to be reproduced and any attempt to classify butterflies by the larval forms would certainly throw the usual system into chaos. No two perfect insects more closely resemble each other than do the Large White, *Pieris brassicæ*, and the Small White, *P. rapæ*. Indeed, all but practised entomologists look upon one as merely a larger one than the other. Yet the difference between their larvæ is simply enormous. The small one is bright soft green, with only the faintest of markings and a nearly smooth body, while the large species has a caterpillar bluish green in colour, and dotted over with black warts studded with hairs.

In varying families, each different method is more or less developed, though perhaps green colouring, corresponding more or less perfectly with the environment, is the most general. Shape varies immensely, not only in different families, but in individuals of the same family, and forms commonly known as "woodlouse" shaped, from their extremely contracted appearance, are met with in several groups. Hairy, spiny, and wart-bearing species are common, and the protective devices of the Puss Moth are possessed by a whole group of butterfly caterpillars. In the Swallowtails, the forked appendage is found as a regular feature, but, instead of being placed on the last segment, it is on that immediately behind the head. In this case it is the seat of a powerful and not pleasant odour, which by implication must be regarded as a protection against enemies. The acid ejection occurs among several Vanessa larvæ, but, in this case, is not thrown to a distance, but merely discharged in a large drop when the insect is interfered with. Silk is utilised in only a few cases, generally to form a common web under which the whole brood feed during the earlier part of their lives.

Evolution of form must, of course, be allied to or correlated with evolution of habit, and this fact should never be lost sight of, if a true view of the complex causes which have led to the immense variety of form found amongst lepidopterous caterpillars is to be obtained. As we have seen, there is scarcely any marked deviation from the simple grub type, until habits of roaming abroad for food are acquired. Conversely, the habit of roaming could scarcely become profitable unless qualities were acquired which counteract the risks occasioned by it. How delicately this correlation is adjusted may perhaps be best understood by the consideration of one or two individual cases. Take that of the Privet Hawk Moth, for example. Large and conspicuous though this insect is when studied as a solitary object, I know from experience that, when feeding on its native bushes, its green colour, broken by the oblique white stripes, conceals it so effectively that it is not an easy matter to find one or two out of several dozens which may be feeding in quite a limited area. Place one on the ground and it instantly stands out as a most startlingly definite object. The Privet caterpillar goes down to the ground at the end of its term, for its pupa is invariably placed beneath the soil. At this time, however, its green colour has faded, and, in its place, the whole of its back becomes a dirty brown shade, making it far less conspicuous on the earth. This can hardly be held a mere coincidence. Another example is that of the Swallow-tail caterpillar. When very young, this creature feeds in the flowerheads of fennel and the middle of its body, which is dark green, is crossed by a broad white band, so that it is by no means easily picked out on the flowers. When it moults, it loses the white patch and becomes uniformly light green, with black rings and red spots, and, although it may not be regarded as a very striking example of protective coloration, its new form is certainly better adapted to its new position among the bright green fennel leaves than the earlier white marked stage would be.

However we may regard any individual case which seems to present difficulties, the fact stands out that variation in form increases progressively with the advance from secluded habits of life to the active ones of the open, reaching the maximum in the diurnal butterflies.

# NOTES

**Scientific Politics.—VI. The Theory of the State.**

THERE have been as many theories of the State as of sex, most of them equally disputable. But the controversial point about sex is its beginning, that of the State its end. No biologist ever doubted the function and purpose of sex. Every politician has a different view of the function and purpose of the State.

Its primitive purpose, however, is not in doubt : it was an insurance corporation. Every State is historically a union of men for defence (sometimes for offence) ; and it seems certain that its other internal characteristics are only adaptations, and often merely local adaptations, of the corporation to that end.

The family is an enlargement of the individual ; the herd, tribe, nation, State are successive extensions of the family. Each has been evolved as a defence against accident, disaster, and external aggression ; each presupposes the co-operation and occasional sacrifice of the unit for the mass ; each recognises that the unit is mortal and proceeds on the assumption that the mass is immortal. The State may take many forms : a theocracy, autocracy, democracy ; or it may be a State within a State, a religious sect, a learned society, or a trade union ; but always it is first and foremost a study in continuity.

The State, like all insurance corporations, deals in selected lives. In the more primitive States superfluous infants are exposed, and in times of stress the aged are put to death and even eaten ; a method of turning the consumer to account as a producer which might be defended theoretically by a strict economist, but will hardly be advocated in practice—if only on the grounds of good taste—by contemporary society.

The civilised State is therefore less strict in its selection of lives than its savage ancestors ; indeed, in some ways it has reversed the older methods. Directly or indirectly, the State subsidises every child in Britain to-day, by allowance on parental income-tax, by free education, and, in some cases, free meals at school. And so far from disposing of the aged as useless mouths, it endows them with a pension.

Whatever may be alleged against civilisation as intensifying the struggle for existence during the more active years of life, it at least renders the period of our first and second childhood more tolerable. Its indiscriminate protection of infancy and youth might possibly be challenged as a merely calculated and selfish policy, since the continuance of the State itself ultimately depends on the supply of youth ; but the endowment of age seems proof positive of a real ethical improvement.

Ethics, however, have a disconcerting habit of dependence on economics, and it will perhaps be wise to suspend judgment on that point. The actual cost of old age pensions is relatively small, and a comparison between these and the figures for defence will show that the State is still primarily an insurance corporation, and only in very minor degree a provider of endowment assurance. That department of life it still leaves in the main to the individual, or at least to the family.

The fact that the modern civilised State exercises no such stringent form of selection of lives as its primitive predecessor may possibly indicate what theologians call " a change of heart " ; one hopes it does. But quite obviously it indicates that the selection has been relaxed because the basis of the State is now broader, and the business of carrying it on involves a great deal more than the primary necessity of defence against external aggression. The modern State admittedly requires soldiers, and in grave emergencies, when its own continuity is threatened, every subsidiary purpose still goes by the board, and every man is required to be a soldier. But in normal times it requires many other types of men ; and it seems probable that the greater the variety of men it can produce the stronger will that State be. The State is not a farmer who breeds for one particular purpose. The suspicion that this is one of the underlying ideas of eugenics probably accounts for some of the public distrust of that society.

There exists, however, another and supremely important form of life selection controlled by the State, which is ignored by most political theorists. The State incarcerates both its criminals and lunatics, and thereby forbids them to propagate their kind, at any rate during the period of incarceration. But the prohibition is only indirect, and therefore (except in the case of actual idiots) it is almost wholly ineffectual ; for both criminals and lunatics are prolific, and both have generally produced their offspring already before the prison or asylum door closes behind them. And experience shows that these are likely to be a double burden to the State, for not only can the parent not support them while under lock and key, but the children themselves are already tainted, both by heredity and environment. The State, in rearing them, is likely to be at a double loss—it is paying for the maintenance of the very type that is least likely to be of service to it.

The eugenic aspect of the question lies outside, although only a little way outside, the field of political science. But it is to be noted here that (*a*) the modern civil State restricts the liberty of its subjects or citizens in many necessary (and conceivably some unnecessary) ways, but in no case does it directly forbid them to increase and multiply. It insists, indeed, that they shall support their progeny, but every magistrate knows that the provisions and penalties to that effect are largely illusory. And (*b*) the only precedent for sexual restrictions of this kind occurs in the theocratic State. The curious effects which this produces are worth a moment's notice.

The Roman Church is in many ways the ideal type of theocracy. The mere fact that it is far older than any existing civil State in Europe shows that it has solved the fundamental problem of Governments—that of continuity—with success. And it has solved it, paradoxically enough, with subjects who are one and all sworn to celibacy. The symbolism of parentage —" Holy Father " and " Mother Superior "—is preserved, but this is purely mystical ; the genealogical tree of the Church is the apostolic succession.

Any system of policy which can last nearly two thousand years must be regarded with respect, and even with astonishment, by the student of statecraft. We are not concerned here with religious doctrine ; but the following factors have obviously played their part in preserving the stability of the Catholic Church.

I. Being celibate, its selection of lives has been far more drastic than in the civil State, where selection hardly exists at all. The Church can, of course, only accept those who offer their services, but it can reject anybody it pleases. It is to be presumed that it consistently rejects all demonstrably unsuitable applicants. In the case of the Jesuits, at least, Loyola imposed a strict system of selection, and a long period of training, during which he invariably rejected all candidates and novitiates who in any way fell short of his demands. This fact alone gives the Church an enormous advantage over the secular State; in that sense, it approximates to the very highest type of insurance corporation.

II. It escapes the prime cost of rearing its subjects during their unproductive years. This fact accounts (more largely than Protestant propagandists have found it convenient to admit) for much of the wealth of the Church.

III. It is necessarily communist, which no civil State can be. The civil State is an enlargement of the family, and the family remains at once its basis and its inevitable limitation. The Church dispenses with the family altogether, with the result that its professed subjects are amenable to a single unitary discipline, and consequently owe but one allegiance. A member of a civil State has a duty to his family and a duty to his State, and the two sometimes conflict—they would conflict more often were not secular statesmen (who are usually heads of families) scrupulously careful to respect the dignity of the family. But by doing so, they limit the power of the secular State. The Church has no such calculations to make.

The communist State is therefore radically different from the ordinary State. It is not faced by the necessity to compromise at its very threshold ; it is more disciplined, and its method of selection, and consequently of promotion, is more strict. It has manifestly many advantages in the struggle for life, which is as keen between States as individuals, and these advantages have helped it to survive longer than any secular organisation.

But these advantages are not transferable to the secular State. The Church is recruited from the secular stock of population. If the whole population took holy orders and the vow of celibacy, the triumph of the Church would indeed be complete. But it would be short-lived, for it would have no further recruits, and within a generation humanity, the State, and the Church, would be extinct. Communism can only exist as a parasite on the family ; so long as it only selects a few individuals from the mass, it can thrive, but when it kills the host it kills the guest.

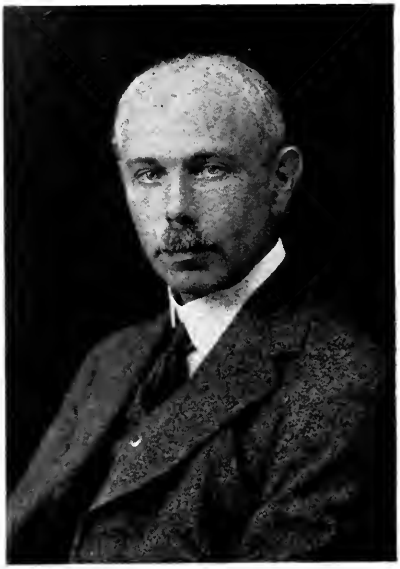
The secular State, then, is thrown back on the individual and the family, and it cannot restrict their liberty as the Church can restrict the liberty of its voluntary associates. Since partnership in the State is involuntary, the chain must not be made too heavy, or it will snap.

**The Late Professor Röntgen.**

Prof. Wilhelm Konrad von Röntgen, whose death at Munich was announced on February 10, was born at Lennep, in Rhenish Prussia, on March 27, 1845. He was educated in Holland and at Zürich, where he obtained his doctrate in 1869. Soon afterwards he was appointed assistant to Prof. Kundt, and worked in that capacity first at Würzburg and then at Strassburg. In 1875 he was appointed professor of mathematics and physics at the Agricultural Academy, Hohenheim, in 1876 he returned to Strassburg as extraordinary professor, and three years later went to Giessen as professor of physics and director of the Physical Institute. In 1885 he was elected to the corresponding chair at Würzburg, and it was during his tenure of this office that his recognition of the X-rays as a new type of radiation and his investigation of their properties brought him world-wide fame. After his discovery he was appointed professor of experimental physics and director of the Physical Institute at Munich, a post from which he resigned only in 1919. His work was honoured in England by the award of the Rumford Medal of the Royal Society (jointly with Prof. P. Lenard) in 1896. In 1901 he received the Nobel Prize for Physics. Previous to his discovery of X-rays he carried out research in many different branches of Physics, including elasticity, capillarity, the conduction of heat through crystals, the ratio of the specific heats of gases, the electromagnetic rotation of polarised light, etc.

X-rays had really been detected before Röntgen's investigations by Hertz and by Lenard, who placed an aluminium window opposite the cathode of an exhausted tube and obtained rays in the air outside which affected a photographic plate placed in their path. Lenard stated, however, that these rays were deflected by a magnetic field and, in consequence, he identified them with the cathode rays. Röntgen's discovery resulted from his observation that a barium platinocyanide screen fluoresced when placed near a Crooke's tube (of the type used to demonstrate the shadow cast by the cathode stream) even when the tube was covered with black paper. He investigated the phenomenon very thoroughly for several months, and towards the end of 1895, published a paper in the *Sitzungsberichte der Würzburger Physik-medic Gesellschaft* (translated in *Nature*, 1896) which contained a description of all the simpler and well-known properties of the rays with the exception of their effect on the electrical conductivity of air. In particular it was shown that the rays are produced by the impact of the cathode rays on the glass walls of the exhausted tube and that they are not reflected or refracted (*e.g.* by prisms of water or glass, etc.) as light rays are. Röntgen was thus led to abandon his original idea that the rays could be classed with ultra-violet light, and suggested that perhaps they might be longitudinal æther waves.

The announcement of the discovery created enormous interest in the daily press as well as in scientific circles. The first public demonstration in this country would appear to have been that given by A. W. Porter at University College, London, on January 30, 1896, with a Crooke's focus tube, *i.e.*, a tube with a concave cathode which focused the cathode stream on a sheet of platinum held in the centre of the bulb. The photographs obtained with this tube were much sharper than those obtained by Röntgen and, in a discussion which took place at the Royal Society on February 13 after J. J. Thomson had described the effect of the rays on the conductivity of air, Porter gave an account of an experiment which showed that the



DR. F. W. ASTON.

PROF. F. SODDY.

X-rays originated at the platinum target. Only a fortnight later, on March 3, C. T. R. Wilson described to the Royal Society the effect of the rays in providing nuclei on which water vapour could condense when it was subject to sudden expansion. The later researches on the properties of the rays, which may be said to have culminated (on the physical side at least) with their application to crystal structure, will be familiar to readers of Science Progress. It may, however, be interesting to note that the method of reflection at grazing incidence which finally settled their nature was tried by Fitzgerald and Trouton in Dublin as early as 1896, but these investigators used lead and paraffin wax as reflecting surfaces. Röntgen himself, in his original paper, had described experiments which may be regarded as the prototype of those performed by Laue, to see whether the geometrical arrangement of the molecules in iceland spar and quartz had any effect on the rays, but without obtaining any positive result.

## The Nobel Chemistry Prizes for 1921 and 1922

### Dr. F. W. Aston.

Dr. F. W. Aston, who was awarded the prize for 1922, was born on September 1, 1877, at Harborne, Birmingham. He was educated at Malvern College, and the Universities of Birmingham and Cambridge. After a year spent as assistant Lecturer in Physics at Birmingham he entered the Cavendish Laboratory in 1910, obtained his B.A. by research in 1912, and was appointed to the Clerk Maxwell studentship in 1913. During the war he held an appointment on the technical staff of the R.A.F. at Farnborough. Returning to his researches at Cambridge in 1919, he rapidly attained success with a new method of positive-ray analysis. In 1920 he was elected to a Fellowship at Trinity College and received the Mackenzie-Davidson medal of the Röntgen Society; in 1921 he was elected Fellow of the Royal Society. His work first came into prominence at the B.A. meeting in 1913 owing to the communication of a preliminary account of his attempts to separate from the element neon (atomic weight 20·2) a second element of atomic weight 22, whose existence was indicated by Sir J. J. Thomson's experiments with positive rays. Prolonged fractionation of the two gases by absorbing them in charcoal cooled by liquid air (whereby the absorption of the heavier constituent was expected to be greater than that of the lighter) having failed, Aston had designed an automatic apparatus in which the two gases were continually diffusing through a pipeclay tube, and announced that he had succeeded in dividing the original gas into two parts of which one had a slightly greater density than the other. This was considered at that time as being the first separation of a non-radio-active element into its isotopes, and the element of atomic weight 22 was called metaneon. The diffusion experiments were continued until they were interrupted by the war, at which time no really decisive evidence for any such separation had been obtained.

After the war, however, Aston placed our knowledge of the isotopic character of the elements on a firm basis by means of the apparatus known as the mass-spectrograph which he himself described in Science Progress

(October 1920). This apparatus was an improvement on that used by Sir J. J. Thomson in his positive-ray work. In Thomson's arrangement a narrow circular beam of positive rays was so deflected by electric and magnetic fields that particles having the same value for the ratio of charge to mass produced a parabolic line on a photographic plate; in the improved method a very narrow ribbon of rays was deflected so that all such particles are brought together to form a short narrow line on the plate—a mixture of particles of different masses giving a *mass spectrum*. With this apparatus differences of atomic mass of the order of 1 part in 1,000 could be detected, and the result, as far as neon is concerned, was to show that there is no element of atomic weight 20·2, but only a mixture of two of atomic weights 20 and 22. Further investigation has shown that the majority of the chemical elements are mixtures of isotopes whose atomic weights are all whole numbers on the oxygen scale, and has also demonstrated the existence of *isobares*, *i.e.* elements of the same atomic weight but with different nuclear charges and therefore with entirely different properties.

When Dr. Aston wrote for SCIENCE PROGRESS he had dealt at least provisionally with eighteen elements; his book *Isotopes* (published by Arnold in 1922) contains an account of his investigation of many others. In this brief note it only remains to pay a small tribute to the extraordinary skill and patience which his work has involved.

**Professor Soddy (A. S. Russell, D.Sc.).**

Although Englishmen have been not ungenerously helped to Nobel prizes in physics, the late Sir William Ramsay and Sir Ernest Rutherford are the only British-born men who have preceded Prof. Soddy in gaining the Nobel prize in chemistry. Indeed, as the first of these was a Scot and the second is a New Zealander, Prof. Soddy has the distinction of being the first English-born chemist to receive this prize. He is also the first Oxford professor to receive a Nobel prize in any subject.

Prof. Soddy passed from Eastbourne College *via* University College, Aberystwyth, to Merton, Oxford, becoming a Postmaster there in 1895, and taking a first in chemistry in 1898. In 1899 he was appointed a demonstrator at McGill University, Montreal, where Sir Ernest Rutherford had been appointed professor of physics in the preceding year. His first published research was of importance. He gave the correct interpretation of Crookes' work on the separation of the body uranium X from a solution of uranium by showing that it was the radio-activity of uranium itself which led to the production of uranium X. Later he joined hands with Prof. Rutherford, and the physical measurements of the latter and the chemical work of the former and the ideas of both led to a series of most important discoveries. Their chiefest contribution to science was their explanation of radio-activity, which has not only stood the test of twenty years' subsequent work, but has in fact inspired every single later experiment and been at the base of every subsequent hypothesis. This is too well known to require description here. They showed that the transformation of one element into another, which the alchemists dreamt about but never achieved, was actually taking place in nature, but with this difference, that it was *spontaneous* and could not be influenced in any way by man, and with this addition, that the energy unlocked by the atom in transmuting itself, and not the element resulting from the transmutation, was the matter of importance.

The suggestion of Rutherford and Soddy that the gaseous element helium might be one of the transformation products of a radio-element received brilliant confirmation by the latter in Sir William Ramsay's laboratory in London in 1903. Soddy and Ramsay examined the gases given off when first an old quantity and second a freshly prepared quantity of radium was dissolved in water. They showed by the spectroscope that helium was present in the first and not in the second. Four days later, however, the second showed also the spectrum of helium. These experiments proved that not only was helium present in old preparations of radium, but that helium was produced directly by the transformation of radium and its products. This discovery was of great importance, because it was the first definite evidence of the production of a known element from another.

After settling in Glasgow in 1904 as Lecturer in Physical Chemistry at the University, Mr. Soddy commenced a long and difficult research on the parent body of radium. Radium was thought to be connected in some way with the radio-element uranium, but the relationship was obscure. It was possible that between the two there stood one or more elements of relatively long life-periods. Mr. Soddy carefully purified several large quantities of uranium, and measured from time to time, over a period of years, the rate at which radium was being formed in them. The rate was exceedingly slow, and the mesaurements difficult to make, but by working out a very delicate way of measuring radium in excessively minute amount, and exercising the most scrupulous care, Mr. Soddy was able to solve his problem successfully. He found eventually that between uranium and radium there lay one element with a life-period of about a hundred thousand years. Years later, when knowledge of radio-activity was very much greater, it was found from other evidence that only one body did lie between, and that its period actually was about a hundred thousand years!

One of the most illuminating subjects on the border-line of physics and chemistry at the present day is that of "isotopes." In 1910 knowledge concerning the chemical properties of most radio-elements and their relationship to the common elements was in a state of chaos. By 1913 everything was straightened out and the major difficulties solved. Much of the credit for this important simplification goes to Mr. Soddy. He found that it was possible for two distinct chemical elements ("isotopes") to be so similar in all their chemical properties that, although recognisable as individuals when separated, they were indistinguishable and inseparable when mixed. This fact has led to some very important developments in our knowledge of the structure of an atom. And it has had this practical use, that the properties of several elements have been predicted with certainty from knowledge of but one particular property of them. More particularly it has led to the discovery of a few radio-elements. And the most important of these, the parent of actinium, was discovered in 1917 by Prof. Hahn and independently by Mr. Soddy himself, a practical piece of work directly suggested by his own theory.

Mr. Soddy has done important work on several subjects besides those mentioned in this brief survey, notably that on high vacua with his calcium furnace, on the separation of radium and mesothorium, on the "end-products" found in radio-active minerals, and on the gamma-rays—the exceedingly penetrating X-rays—spontaneously emitted by certain radio-elements. Much of this is pioneer work and of great importance.

### Les Prix Nobel.

The annual publications of the Nobel Committee called *Les Prix Nobel* and issued by P. A. Norstedt & Söner, Stockholm, are always extremely interesting reading because they give in detail the work of the Nobel prizemen of the year, described by themselves, together with an account of the ceremony of distribution in the year concerned, written in French. The publication is beautifully printed, and illustrated with admirable portraits of the laureates, and the whole series, which is probably possessed by few, contains an almost unique history of science since 1901, and in fact from before that date. Most of the contributions are in English, French, and

German. The issue for 1919–20 contains accounts of the ceremonies of distribution on June 1, 1920, and December 10, 1920, with portraits and biographical notices and the Nobel lectures delivered by the laureates. These were Max Planck, Johannes Stark, Fritz Haber, Charles-Edouard Guillaume, Jules Bordet, August Krogh, Carl Spitteler, Knut Hamsun, Woodrow Wilson, and Leon-Victor-Auguste Bourgeois.

### The Jenner and Pasteur Centenaries (Col. W. G. King, C.I.E., I.M.S., M.B., D.P.H.).

According to the Registrar-General, in 1922 London, which (including its " outer ring ") has a Census population of over seven millions dependent on water derived from a source which sanitarily must be classed as "suspicious," and on the removal of waste products which demand for safe-conduct that not a lapse of structure nor a default in organisation of personnel shall mar its daily routine, had a general death-rate of 13·4 per mille of its population, and an infantile death-rate of 73 per 1,000 births. The rest of England and Wales, implying inclusion of both urban and rural populations—the latter supposedly rich in possession of abundance of unused air—yielded 0·5 per mille less in its general death-rate ; but for every 1,000 births consigned 4 more to premature death than crowded London. But in this London, in 1660–79, the general death-rate was 80, in 1746–55, 35·5, and in 1881–90, 20·3 per mille. In 1730–49, of children living under five years of age the death-rate was 75·4 per cent. From the single disease small-pox, the average annual death-rate of the population of England, during the period 1730–49, was 5 per mille.

These figures, when reckoned upon populations of many millions, imply in difference of rates enormous saving of life per annum in this country and, further, that the increments of saving have been attained within the past century. There can exist no difference of opinion that this result has been brought about by the application of methods of disease prevention which have become available in that period.

Up to the end of the seventeenth century, the protection of life was based on methods which were empirical. Conditions which might be but adjuvant were, by their repeated yet exceptional occurrence, forced upon attention, and were interpreted as the causative agents. Thus, foul odours and fluctuations in meteorological conditions[1] gave much room for grave discussion. But, in the process of evolution, man in common with other denizens of the earth has purchased his improved condition at the cost of experiences—many of which, though impressive, might, at the time of infliction, have been decidedly disagreeable. Certainly, subjection to epidemics of small-pox might be so described. In England, its demand upon life sufficed to provoke the proverb, " A mother's son is not her own until he has had the small-pox." But, those who survived the infliction were living witnesses to the possibility of immunity to a recurrence of the disease, and gladly submitted to inoculation with its hopeful but dubious issue. It was soon forced upon observation that when the disease attacked bovines and was subsequently acquired by man, it not only afforded protection but was mild in type—an experience which was put in practice by the farmer Jesty. But it required the genius of Jenner to investigate and substantiate the potentiality of the

[1] The latter factor had the merit of irresponsibility in ascribing to Providence that which was beyond the cognisance of the physician. In illustration of this mental attitude may be quoted a report on the health of British troops in India for the period 1829–38, when a death-rate from cholera of 10 per mille was no rare occurrence. The Medical Officer compiling the report stated he did not think it necessary to add the cholera deaths to the general rate, because " in the latter year, as has been mentioned, an unusual state of atmosphere prevailed."

method for the protection of communities. He satisfied himself of the soundness and safety of the practice experimentally in 1796, and thus established the doctrine of immunity, by a process which had brought about attenuation of the then and still unrecognised causative agent of the disease. Received at first, as most new branches of thought or practice usually are, by much incredulity and hostility, Jenner lived to see vaccination eagerly sought for by nations throughout the world. The British Government recognised the public value of his labours by giving him a grant of £20,000, and the city of Calcutta (where 23 per cent. of all deaths were due to smallpox) forwarded to him a thank-offering of £6,000. The life-saving and prevention of maiming of survivors of attacks in populations protected by vaccination are too well recognised in the present day to require comment. The work of Jenner has been followed, as with the proverbial casting of the stone in the pool, by ever widening influence.

Within a month of the death of Jenner (January 1823), there was born the bearer of a name that has become as familiar throughout the world as that of Jenner, namely, the French *savant* Pasteur. The existence of micro-organisms had been recognised as far back as 1659. In 1848, Pasteur performed experiments in fermentation which demonstrated the multiplication of certain of these under special conditions, with the production of specific results. Later, cultivations of a micro-organism derived from instances of chicken-cholera exhibited varying virulence. Using the mild form as vaccine, he secured immunity in fowls. Pasteur thus laid the foundation of that important science—Bacteriology. No longer could Liebeg's theory of the spontaneous origin of micro-organisms be accepted. That great truth, in relation to surgery, was grasped by Lister, with the result that where formerly in careful hands death followed in 10 per cent. of operations, in the present day, not more than 1 per cent. can be so ascribed. Operations formerly dared only as a last resort, are now regarded as a matter of routine. Devaine, who had found bacilli in the blood of sheep suffering from anthrax before the period of Pasteur's fermentation experiments, but without pronouncing their pathogenic character, in the light thus afforded by Pasteur concluded (1865) that these possessed specific qualities. To secure protection of herds of sheep demanded their immunisation. The great mind of Pasteur (1877) conjectured that if in Jenner's vaccination the unrecognised specific causative agent had been modified in passing through bovines, might it not also be possible by artificial means to bring about attenuation of disease-bearing bacilli which were now distinguishable ? This he accomplished. The artificial attenuation doctrine having thus been established, he was led to the discovery of a method of prophylaxis against the development of hydrophobia in the human being, of utility within a period of the infliction of bite by rabid animals. He thus brought the hope to thousands of human beings of rescue from one of the most agonising forms of death conceivable. Pasteur Institutes are now features of preventive medical science wherever the dread disease of rabies prevails.

But the hope of obtaining immunity by attenuated forms of the disease-bearing agent which filled Jenner in approaching anti-variola vaccination, and which in the hands of Pasteur was so magnificently expanded, has borne fruit beyond that anticipated by the latter. Haffkine, pursuing modifications of Pasteur's methods, has excogitated a vaccine against cholera and, notably, against plague, which *should have* earned the undying gratitude of plague-stricken India. In the hands of Wright, vaccine has been produced which has caused typhoid—the scourge of armies—to be brought under control. Whilst improved knowledge as to disposal of infective matter and detection of " carriers " must have contributed to the result, it must be held that the prophylactic use of anti-typhoid vaccine contributed greatly to the contrast afforded by the mortality in the armies employed, respectively, in the South

African War and constituting the Expeditionary Force in France between 1914 and 1918. In the former, of 250,000 men, 8,000 died of typhoid; in the latter, of 2,500,000 men, the total deaths from this disease were 200.

The knowledge of immunity acquired by sufferers from small-pox which first induced the ready acceptance of inoculation by nations, and then the recognition of attenuated pathogenic matter in Jennerian vaccination, has further led to processes for the slow immunisation of animals, with the production of sera, of which the best known are those employed in connection with diphtheria and tetanus. There has also followed, on the principle of gradual building up of the natural resisting powers of the body and thus producing immunisation, the employment of numerous bacterial vaccines.

In short, in the years which have elapsed since Jenner realised the value of attenuation of morbific agents, the power of preventive medicine has been so increased as to rank as the pivot of the welfare and political economy of nations. In this light, at the centenary of Jenner's death and of Pasteur's birth, we recognise with gratitude, in this Briton and Frenchman, ideals which have for their supreme motive the gain of health and suppression of relentless disease in communities, by application of the ever-increasing means yielded by Nature at the behest of unselfish Science.

### Reviews and Reviewers.

On January 9 a dinner was given at the Institute of Journalists in Tudor Street, Blackfriars, by the Circle of Scientific, Technical, and Trade Journalists, after which a discussion on the subject of Reviews and Reviewers took place.

Sir Richard Gregory opened it with an able address in which he discussed many points connected with the subject; and as a number of journalists and editors of technical organs were present, the subject received exceptionally thorough consideration. Most of the speakers agreed that reviews were to be divided into three classes, the descriptive review, the critical review, and the essay-review. Some thought that the first class did not appeal much to readers, but others were not so confident of this; and others, again, divided the descriptive reviews into two sub-classes, namely "catalogue reviews" which merely give the contents of a book, and more thorough notices which indulge in a complete description. On the one side it was argued that readers desire criticism as well as description; but on the other side, that many readers simply wish to know the object and plan of a new book without being much troubled with the opinions of the critic—which notoriously often depend not only upon the merit of the work. It was fairly well agreed that authors have the right to reply to critical reviews which attack or misrepresent them and that their replies should be published. The essay-review uses the book reviewed merely as a peg on which to hang an independent essay, and its value depends mainly upon the reviewer's capacity. An important point raised by Sir Richard was what is to become of the volumes after they have been reviewed. It was fairly well agreed that reviewers should possess them and are fully entitled to sell them. But what are editors to do with the numerous volumes which can be merely mentioned in their book lists, such as reprints, pot-boiler textbooks, and books which do not deal with the subject of the special technical journal concerned? Editors cannot possibly keep such volumes *ad infinitum*, yet publishers and authors complain if they are sold soon after publication. If they are given away, as, for instance, to public libraries, the publishers and authors will suffer just as much or more, and there appears to be no alternative to selling. But a decent interval, depending upon the nature of the book, should be insisted upon. After all the review, or even a mention in the book lists, gives the publisher a *quid pro quo* for the cost of his volume, so that possibly he spends less on advertisement in this way than he would in the usual channels for advertisement. The question was raised whether hostile reviews did much harm to the sale of any book, and the feeling seemed to be that they were apt to do more good than harm. It was, of course, thought improper for editors to make alterations in signed reviews without the reviewer's consent; but they were fully justified in changing unsigned ones, which would be generally held to involve the editor's approval.

### Science and the Gods.

Mr. Walter Leaf has recently issued an anthology called *Little Poems from the Greek* (Second Series, Grant Richards, 5*s*.), in which, amongst many other interesting quotations well translated by himself, he gives the famous epigram of Claudius Ptolemy, the great astronomer who lived in the second century A.D., namely—

"No more am I than mortal man,
The creature of a day;
But when the circling stars I scan,
The planets' mazy way,
My feet no longer tread the sod;
At Jove's right hand I sup,
The very essence of a god,
Ambrosia from his cup."

Probably all of those who are engaged in pure investigation or in consideration of the great problems of nature have also, like Ptolemy, felt that they have supped with Jove. It is to be suspected that this honour happens only to men of science, philosophy, and art. Such may not be often called to the table of kings, but apparently they have the consolation of being sometimes summoned to that of the gods!

### Life in Ireland (from a Correspondent).

The writer lives in Cork, and knows nothing of the life in the countryside. The reader may gather something for himself by noting the numerous cases of burnings of country houses which are at present happening. So far as the professional and upper middle classes in general are concerned, there is at present no special hardship in the cities like Dublin; at Cork, however, things are very bad. People living anywhere in Cork are open to visits from gangs of armed blackguards who may have no nice proper political connections or convictions.

In the Ireland of to-day it is dangerous to have, or to have had, connections with England or with the Free State: the latter case is the more risky. In the streets one sees little which would indicate the seething element below. The Ford car is taking an important part in the course of events; to mention the automatic revolver and the Thompson machine-gun is unnecessary. The latter is a new sort of Yankee machine-gun, which fires about 900 or 1,000 shots per minute: it is so small and neat that two Republican women can, and often do, carry one in parts, with trays of shot, in those little handbags which ladies nowadays affect. Young men in green uniforms (Free Staters) or in mufti (either Republicans or Free State detectives) rush now and then through the streets in Ford cars; these men fight great bloodless battles at the street corners, and in some of the suburbs bands of Republican youths are especially active.

Some years ago the writer's immediate neighbours were nearly all what were called loyalists, and there was a sprinkling of persons who favoured the expulsion of the English. These people, he soon found, were of two kinds:

one was Irish through and through, and for purely patriotic reasons wanted to stop the current which was leading to the centralisation of much of the best Irish life around London, a state of affairs which the Union caused; the other kind was the carrion crow variety: the gentry who were waiting for something to turn up—*for themselves*. They did not care about Ireland, were not even Irish in many cases, and one could have no respect for them.

The English have gone, some few of the crows have got their jobs under the Free State, but Ireland is fast going to ruin. Comically enough, the job-hunters are now having their lives threatened by the Republicans, because they (the former) are servants of the Free State. Nearly all the Republicans are young men; in England most of them would still have been mainly interested in collecting stamps and playing football; but to these young Irishmen the struggle is serious—and some of them, at least, hold their lives in forfeit if they are caught.

Some people have not paid their taxes for three years or more: the Republicans say that those who pay taxes are enemies of the Republic. Irish educational institutions tend to range themselves on one side or the other—a great mistake. In some of the British Dominions, University Professors and Civil Service educationalists must sign a paper swearing to take no part in politics other than registering their vote; in Ireland in the past one University at least allowed its house to be a hot-bed of rebellion.

Many an Irishman now sighs for the good old days, when, if your house was burned, the English taxpayer was waiting behind to pay for Irishmen's amusements. Things are different now: the smug air with which certain Irish newspapers write of trade, commerce, manufacturing, harbours, railways, and so forth, while the countryside burns, the bridges and buildings fly sky-high, is remarkable. "The millennium has come," say they; "the English are gone—see what a great country is ours."

There are now commissions on this, commissions on that—commissions on growing turnips, commissions on making Irish cigars—great plans for world commerce, while the Irishman works less than any other European workman, and demands higher wages. The American Ambassador said recently that there were five Yankee trusts, any one of which would finance Ireland. We doubt whether any American sausage and tinned botulism trust would erect factories to be seized by the work-shy Irish Communists and Bolsheviks, and, moreover, the Americans seem rather fond of their money. Of course the past American contracts for sending Thompson's machine-guns to Ireland were a different thing—that was good business.

As for Irish Science, it was partly housed in the College of Science, a costly and beautiful Dublin institution now occupied by the Irish Government. There is barbed wire over the lower windows; strong guards are near-by, and an armoured car or two waits at the corner; inside, the Government work, sleep, and eat. Members of the Senate and Dail are "not at home to-day, thank you," when the armed Republican youths come with a Thompson, a few automatics, and a land mine just to add interest to the call.

Now, if you do not pay your taxes, the Free State is going to call with an armoured car and an empty lorry for your furniture. It will be sent to Belfast or London, to be sold; because in Dublin everyone is trying to sell something now and the marts are rather full.

Mr. de Valera, a Chancellor of the National University, is in hiding in Dublin, has been interviewed for a special column in the *Daily Mail*, and thus takes his place among Signor Marconi's "Wireless Messages from Mars," Mr. Huxley's "Thyroid," and the other startling features of that journal. Mr. de Valera, who once tried for a scholarship in Trinity College, Dublin, and came bottom on the list, and in a fit of temper allowed himself instead to be elected Chancellor of the National University, has told everyone not to pay taxes to the "Imperial Exchequer," *i.e.* Free State.

In the meantime anyone who can afford to leave the country, and to go and live among the base and brutal English, is doing so.

Those who cannot go are taking an interest in commissions on growing turnips; these are to be planted on the burnt-out sites because ashes are good for plants.

The journey from Whitehall to Dublin only takes eleven hours.

## Notes and News.

In the New Year Honour List it was announced that Mr. B. H. Spilsbury, Hon. Pathologist to the Home Office, would receive a Knighthood. Prof. Orme Masson, of the University of Melbourne, was promoted from C.B.E. to K.B.E., and Mr. F. E. Smith, Director of Scientific Research, Admiralty, from O.B.E. to C.B.E. Dr. J. W. Evans, the representative of the Colonies on the Governing Body of the Imperial Mineral Resources Bureau, was appointed C.B.E., and Dr. N. Annandale, Director of the Zoological Survey, India, C.I.E.

The names of the candidates recommended by the Council of the Royal Society for election as Fellows are as follows: Dr. E. D. Adrian; Dr. W. Lawrence Balls (Chief of the Experimental Department of the Fine Cotton Spinners' Association); Prof. A. Barr (Chairman, Barr and Stroud, Ltd.); Prof. C. H. Desch (Professor of Metallurgy, University of Sheffield); Prof. E. Fawcett (Professor of Anatomy, University of Bristol); Prof. F. Horton (Professor of Physics, Royal Holloway College); Dr. R. T. Leiper (Professor of Helminthology, London School of Tropical Medicine); Prof. J. W. McBain (Professor of Physical Chemistry, University of Bristol); Prof. J. J. Rickard MacLeod; Dr. G. A. K. Marshall; Sir Douglas Mawson (Professor of Geology in the University of Adelaide); Dr. W. H. Mills; Dr. J. S. Plaskett; Prof. H. R. Procter (Emeritus Professor of Applied Chemistry, University of Leeds); Prof. W. Wilson (Professor of Physics, Bedford College, London).

The Buys Ballot medal, which is awarded every ten years for distinguished work in meteorology, has this year been given to Sir Napier Shaw.

Prof. E. H. Starling has been appointed first Foulerton Professor of Physiology of the Royal Society.

Among the men of science who passed away during the last quarter were the following: Sir I. Bayley Balfour, late Regius Keeper of the Royal Botanic Gardens, Edinburgh; E. Bouty, Professor of Experimental Physics at the Sorbonne; Prof. A. Horstmann, of the University of Heidelberg, physical chemist; G. Lemoine, Professor of Chemistry at the Polytechnic School, Paris; Sir Norman Moore, late President of the Royal College of Physicians; Prof. J. Orth, pathologist; Prof. W. Röntgen—the discoverer of X-rays; Lord Sudeley.

Sir Arthur Keith has been elected Secretary of the Royal Institution in succession to the late Col. Grove-Hills.

Mr. C. G. Darwin, F.R.S., Lecturer in Mathematics at Christ's College, Cambridge, has been appointed to the new Tait chair of Natural Philosophy in the University of Edinburgh.

Prof. G. T. Morgan has been awarded the Research medal of the Company of Dyers for his paper on the Co-ordination theory of valency in relation to adjective dyeing.

Prof. Graham Kerr, in a long letter in *Nature*, refers to Dr. Smith Woodward's address to the Linnean Society entitled "Observations on Crossopterygian and Arthrodiran Fishes." Prof. Kerr does not believe that the pentadactyle leg has evolved from the paired fin, but he believes that each has evolved out of an ancestral, more or less styliform, type of limb.

Dr. Smith Woodward has mentioned that up to the present there has been a failure to discover fossil links between the paired fin of the Crossopterygian and the leg of the terrestrial vertebrate. In his recently published book on embryology, Prof. Kerr has given an account of the origin of the pentadactyle limb according to his theory.

The retirement is announced of Mr. R. I. Pocock, of the Zoological Gardens, Regent's Park. Dr. Pocock has been a well-known figure in English zoological circles for some years, and he has carried out his duties at the Gardens with the greatest courtesy to everyone who has had reason to consult him. He has published a large number of memoirs on the osteology and morphology of mammals, and is a Fellow of the Royal Society. We offer him our congratulations and our best wishes for the years of his retirement.

He is being succeeded by Dr. Geoffrey Marr Vevers, who is at present Beit Memorial Research Fellow at the London School of Tropical Medicine. Mr. Seth-Smith and Mr. E. Boulenger will continue in their old positions, and Miss I. Cheeseman will be curator of insects.

The death is announced of Prof. Oscar Hertwig, of the University of Berlin. He was one of the greatest of German biologists and had published a number of important textbooks. It was Oscar Hertwig who worked out the nature of the Polar bodies, and in the field of human embryology his contributions were considerable. The brothers Hertwig first worked out in 1875 the fertilisation process of the animal egg, accurately following the behaviour of the nuclei.

Our last number went to press too early to comment upon the presentation to Sir Edward Sharpey-Schafer, by his associates and pupils, of the bas-relief plaque of himself, as a token of esteem by those who had been trained under him, and who occupy important posts, not only in the British Isles, but also in the Overseas Dominions, in the United States of America, and in Japan.

A pamphlet entitled *Suggestions for the Prevention of the Decay of Building Stones*, by J. E. Marsh, M.A., F.R.S. (Oxford: Basil Blackwell, 1*s.* 6*d.* net), contains a most interesting discussion of the causes of stone decay and of the methods which have been suggested during the last seventy years to check the process. Decay is usually attributed to frost or the action of sulphuric acid fumes in the atmosphere, but the author considers that nitric acid is by far the most destructive agent on account of the great solubility of calcium nitrate in water. He suggests that the nitrate is formed from atmospheric ammonia by the action of micro-organisms in the stone, and as a remedy for decay proposes that it should be made sterile by washing every five years with a dilute solution of caustic soda. It is not improbable that the efficacy of limewash is due to its alkaline property.

A certain amount of information is now becoming available concerning the production of helium from natural gas. During the war Prof. McLennan, with the assistance from the staffs of the Universities of Toronto and Alberta, constructed and worked a semi-commercial plant at Calgary at a cost of less than fivepence per cubic foot of helium. From this plant a large quantity of helium of high purity was obtained, and the experiments were regarded as the beginning of an attempt to place the utilisation of the gas, which constitutes one of the natural resources of Canada, on an industrial footing. Quite recently Prof. McLennan has succeeded in liquefying helium in the cryogenic laboratory of the University of Toronto—an achievement previously accomplished only in the world-famous laboratory at Leyden. Large quantities of helium have also been produced in the United States, and Dr. Richard B. Moore, chief chemist of the U.S. Bureau of Mines, states, in *Nature* (January 20), that the Linde helium plant at Fort Worth, Texas, is now producing 15,000 cu. ft. of 93 to 95 per cent. helium per day from the natural gas obtained from the Petrolia field in Texas. It is expected that this output will shortly be increased to 90,000 cu. ft. per day, and present research is being directed to the decrease of the cost of production. Repurification of gas which has been used in dirigibles is effected by the use of charcoal at low temperatures, the entire plant required for this purpose being carried from place to place on two railway cars.

Capt. G. H. Wilkins, who accompanied the *Quest* expedition under the late Sir Ernest Shackleton in the capacity of naturalist, left England on February 20 for Australia, where he is to lead a small party to Northern Queensland in order to obtain a collection of the mammals of the Australian tropics. The expedition, which is under the direction of the trustees of the Natural History branch of the British Museum, is expected to last two years. The other members will be gathered in Australia and will include an ornithologist, a mammalogist, a zoologist, an entomologist, a taxidermist, and probably a geologist. They will travel by caravan to Northern Queensland and thence by schooner to the coast islands, for it is intended to direct special attention to the alterations in animal life consequent on island isolation. Two American expeditions have already visited these regions and have obtained excellent collections for the museums of New York and Washington. The collection in the British Museum, however, is very inadequate, and since it is anticipated that within ten years certain species will be entirely extinct, the need for the expedition has become most urgent.

During the year 1922 there were about a hundred fatalities due to accidental gas poisoning, and considerable uneasiness has been caused by the fact that a Committee, appointed by the Board of Trade under the Gas Regulation Act of 1920, recommended that there should be no limitation upon the proportion of carbon monoxide in public gas supplies. In a letter to *The Times*, dated January 10, Prof. Bone states that a straight coal-gas contains not more than 7 or 8 per cent. of carbon monoxide, a not very dangerous proportion. At the gas-works, however, it is customary to mix with the coal-gas blue water gas which contains from 42 to 45 per cent. of carbon monoxide, and is, therefore, very dangerous indeed. As far as London is concerned, the officials of the various gas companies have declared that there has been no substantial change in the composition of the gas since 1914. This makes it difficult to explain the accidents which are now so frequently reported; at the best it shows that the gas supplied for domestic use is already sufficiently dangerous and that no increase in its poisonous content should be permitted. It is of course possible that no large increase in the number of fatalities has really occurred because, once public attention is directed to accidents of a particular kind, every case is reported in the Press. (It is understood, for example, that therein lies the explanation of the apparent increase in the number of anthracite stove explosions in France.) Pending evidence of this kind, there would appear to be real ground for uneasiness, and if further fatalities occur the demand for an official inquiry should be irresistible.

The Report of the Council of the Royal Society for 1922 shows that the affairs of the International Catalogue of Scientific Literature are in a very serious condition. At the International Convention summoned to consider them on July 22 and 24 last, the Royal Society stated that it could no longer accept the responsibility for the publication of the Catalogue and that it proposed to use all the material in its possession to assist in discharging the liabilities of the Catalogue. These amount to nearly £12,000, including a loan of £7,500 from the Royal Society, £1,200 accrued interest thereon, and £2,242 for printer's bills upon which interest is being paid. The Convention agreed to these proposals and, looking forward to the time when publication may be resumed, expressed the hope that the work of the Regional Bureaux might be continued so that, thereby, the international organisation might be kept in being.

Technical Paper No. 5 of the Fuel Research Board (H.M. Stationery Office, price 3*d*. net) is entitled *An Apparatus for the Measurement of Specific Gravity* *of Gases in Small Quantities.* The title is somewhat misleading in that the term "small quantities" is to be interpreted in a manufacturing sense, the volume of gas required for a complete determination being 1,500 c.c. The method employed is a slight modification of one described by Sir Richard Threlfall in 1907, and involves the balancing of columns of air and gas 24 ft. long against each other.

Special Report No. 9 of the Food Investigation Board (H.M. Stationery Office, 1*s*. 6*d*. net) contains an account of experiments made by Dr. Ezer Griffiths and Mr. A. H. Davis on the transmission of heat by radiation and convection in continuation of those on conduction already dealt with in Report No. 5. The experiments were originally started in connection with heat insulation for cold storage work, but later on their scope was extended, and the exhaustive investigation of the process of convection from flat plates and cylinders described in this Report should be of material assistance in extending our theoretical knowledge of this difficult subject. The results obtained are by no means simple, but they show that the heat lost by convection is proportional to a power ($n$) of the excess temperature of the surface above its surroundings, which is very nearly constant and may be taken as 1·25 for temperature excesses up to 100° C. This result is in good agreement with that ($n = 1{\cdot}3$) obtained by Kinoshita for radiators. The constant factor in this proportionality varies considerably with the shape and size of the hot body and with the position of any baffle plates placed near it.

In December last the newspapers announced that an American Commission had come to London in order to allot awards for British inventions used by the Americans during the war, and named a very large sum of money amounting to millions as being likely to be distributed. The Commission was said to be under Col. Jos. I. McMullen. On making inquiries, however, we were courteously informed that the awards were only to be given in respect of British designs of aircraft, their engines and accessories, communicated to or used by the United States during the war. We do not know what has become of any claims which might conceivably be made by other people in respect to inventions which were quite conceivably more important than those of aircraft design and accessories. We are informed that the claims were to be considered by joint sittings of the Royal Commission on Awards to Inventors and the said American Commission for the Adjustment of Foreign Claims. We presume that the claims of medical men, who did perhaps more good than anyone else during the war, are to be rigidly and contemptuously excluded by means of the casuistical arguments already used by the British Commission.

We have seen the proofs of a very interesting book called *The Rhythm of Speech*, by William Thomson, B.A., D.Litt., which will shortly be issued by Maclehose, Jackson & Co., Publishers to the University of Glasgow. The work is a complete scientific treatise on the subject.

# ESSAYS

## THE DOCTRINE OF LUNAR SYMPATHY (Joshua C. Gregory, B.Sc.)

If the language of "the earliest poets . . . was the language of extraordinary occasions,"[1] and if primitive superstitions ignore rational causes because of "the prepotency of the unusual, wonderful, mysterious, in attracting attention,"[2] Democritus may have rightly referred superstitious beliefs in many gods to the impressions made by extraordinary natural phenomena.[3] The remark that biology originally centred on oddities[4] expresses the same belief in the influence of the unusual upon the human mind. The violence of the unusual, its insistence on attention, and the emotion it stirs seem to qualify it for pre-eminency in stirring and fixing belief. But the vigorous appeal of the unusual may be evanescent. During the annular eclipse of 1919 the Kassena fled to their huts in terror, but when it was over they laughed at their own fears.[5] This evanescence of emotional stir has induced many to disparage the control of the unusual over beliefs. Since life's ordinary round presses continually, it succeeds where the evanescent exception fails, and the usual seems to dominate both human practice and belief. Habits, both of action and belief, are impressed by the continual pressure of the usual. Men are carried along in a stream both by the human society in which they live and by the experiences that surround them from day to day. But the violence of unusual and striking events does, at times, permanently deflect thought. The whole organisation of Lourdes sprang from a vision when little Bernadette Soubirous saw "Our Lady" in the grotto near the wild briar bush.[6] Both the usual and the unusual are potent on the mind: the one because it constantly presses, and the other because it can take the soul by storm. Each is weak where the other is strong: the unusual often failing because it does not continue and the usual because it does not arrest.

The arrestiveness of the exceptional and the steady pressure of the customary are often combined in PERIODIC experiences. Primitive ritual, Miss Harrison remarks, is dominated by the periodic rite which, in its turn, is dominated by the impressive periodic events of nature.[7] The recurrence of spring, with its impressive burst into plant life, centred ceremonial rites upon itself. The wide periodicity of life and nature has impressed many minds. The Greeks chose to represent the universe as a ceaseless transformation without end or beginning, as a succession of cyclic periods that

[1] Wordsworth, *Append. Lyr. Ballads*, 1802.

[2] Carveth Read, *The Origin of Man and of his Superstitions*, p. 122.

[3] Zeller, *Presocratic Philosophy* (Alleyne's trans.), ii, 288.

[4] *The Nation and the Athenæum*, April 16, 1921, p. 102, "The Genesis of Science."

[5] Cardinall, *The Natives of the Northern Territories of the Gold Coast*, p. 24.

[6] Georges Bertrin, *Lourdes*.

[7] Jane Ellen Harrison, *Ancient Art and Ritual*, p. 52.

repeated one another endlessly.[1] "For as though," wrote Sir Thomas Browne, "there were a Metempsychosis, and the soul of one man passed into another, Opinions do find, after certain Revolutions, men and minds like those that first begat them."[2] Now certain periodicities are swift enough to be ordinary experiences and striking enough because of their periodicity to have the arrestiveness of the unusual. The waxing and waning of the moon was as familiar to primitive man as the fire that warmed his hearth and also, in its steady periodic change, arrestive like the mysterious eclipse that sent him trembling to his hut. It was too constant to stir as violently as the eclipse, but its constancy, conjoined with an arrestiveness like that of the unusual which periodicity secured, stirred him to a sense of significance.

The Kassena fear they may become weaker as the moon becomes larger, and, for some obscure ritual reason, blow ashes towards the crescent of the new moon.[3] If they think that the waxing moon absorbs their strength to supply its own growth they are an interesting exception to a very general primitive belief which survives, as a still convinced or half-convinced superstition or as a traditional amusement, whenever fingers turn a coin in a pocket at the new moon: the moon is on the wax and wealth may wax with it. The influence of the waxing moon in urging growth was one of the first recipes for preventing baldness, for Tiberius, according to Pliny, had his hair cut during the moon's increasing phases.[4] For an opposite reason, doubtless, up to the Revolution wood was felled in France after the full moon.[5] Tiberius desired his hair to grow, so it was cut when the moon waxed; builders desired their wood to season by drying, so it was cut when the moon waned. This belief in a connection between increasing or decreasing moons and increase or decrease of all kinds of growth penetrated deeply and extensively into the primitive mind, producing a rich variety of customs and rites and surviving in many superstitions. The sympathetic response in growing things to the changes of the moon seems to have impressed itself as decisively on the human mind as the belief in a circulating sun.

The apparent journey of the sun round the earth depended on an obvious sensible intuition, for the sun SEEMS to our eyes, in spite of our knowledge that it does not, to travel round us. Such a sensible intuition, a spontaneous estimate springing from an appearance to the eye, shaped the mythical thunderbolt. When a flash of lightning rends a tree or shatters a rock or fells a hut there is an appearance of SOMETHING thrown. The vivid flash suggests a THING like a stone; fires and flames, for early thought, were flaming bodies, or, more definitely, the fire itself was a substantial thing. Thus the thunderbolt, a fiery projectile thrown by Zeus, depends as convincingly as the daily journey of the sun on a sensible intuition. The eye sees and the mind forms a spontaneous estimate. If the mythical thunderbolt were a meteor flashing through the sky or a meteorite crashing on the ground, a sensible appearance stirred a spontaneous comparison with the missile of an angered God and the fearful soul SAW, for it would seem in very truth to SEE, an avenging act of Zeus.

Some convincing experience probably compelled the inference that growing things sympathetically responded to the changing moon, since the belief is so widespread and so insistent. The inference probably did not depend so directly on a sensible intuition, on an estimate that so directly prolonged, so to speak, into an inference a simple act of seeing, as did the

[1] Gomperz, *Greek Thinkers*, bk. i, ch. iv.

[2] Sir Thomas Browne, *Religio Medici*.

[3] Cardinall, loc. cit., p. 23.

[4] Fox, SCIENCE PROGRESS, 1922, **17**, 273, "Lunar Periodicity in Living Organisms."

[5] Ibid., p. 274.

conviction that the sun moves round the earth. If the fall of a meteorite were directly identified with a missile from Zeus it was so directly identified because of the preconception that Zeus reigned in the sky, that he would punish presumptuousness, and that he could hurl flaming projectiles from Olympus. Spontaneous estimates may be sensible appearances directed or fashioned by preconceptions, and on such a spontaneous estimate the notion of sympathetic lunar contagion probably depended. The suggestion that because "the moon is one of the most striking of natural objects seen by primitive man, and one which varies most in aspect," then "by association of ideas the moon's increase and decrease is supposed to influence the increase and decrease of any changing process,"[1] does not seem to be complete. The prominence of the moon, which, as the Irishman said, is more useful than the sun because it comes out in the dark when there is so little light, was part, it seems certain, of the convincing experience. But why should a cabbage grow because the moon is growing or Tiberius become bald as it wanes? The association of increase or decrease with growing or changing things by an analogical transfer from the moon's phases must depend on some connection that prompts the transfer. An indirect prompting of growth by the moon was apparently supposed by some to have moisture as its intermediary. Plutarch, for example, says that dew falls most freely at full moon. Fox suggests that the moon was supposed to be a source of moisture because, since dew deposits most on cloudless nights, the moon and dew appear together.[2] This first effort to substitute science for magical belief is, however, later than the ascription of magical potency to the moon and is much less universal. The belief in a sympathetic connection between the moon and growth arose independently of the later "moisture hypothesis," nor does Fox suggest that it did not.

In one group of primitive myths or stories messages pass from the moon to men. The messengers in these stories are instructed to tell human beings that they will rise again as the moon rises after her death. The death and resurrection of the moon obviously represent her waxing and waning phases, or her newness and fullness, and her promise of human resurrection is the same belief, in essence, as the belief that her phases control the crops. If the moon dies and rises again she has, in her turn, been compared to human beings who are observed to die, or to plants which seem to die and bloom again. The stress of the comparison usually falls on the resemblance of growing things to the changing moon. The messengers in these moon stories are usually animals, and the choice of messenger is catholic enough to include the hare, the dog, the insect, and the tortoise. The messenger varies among these animals with the *locale* of the myth—some Hottentot stories, for example, enrol the hare, and a Bushman story enrols the hare and the tortoise. Sir James Frazer[3] includes these stories under "The Story of the Perverted Message." The "perversion" is obviously an attempt to conform the fact that men die without rising with the conviction that they should, through sympathetic response to the behaviour of the moon, rise again after death. The method of perversion varies: a dog angrily told its hosts that they would die and not rise, because it was not pleased with their hospitality; a hare was simply careless and forgot that the moon had promised resurrection to men; an insect, instructed to tell men that they would rise again, passed on the message to a hare, who perverted it into a sentence of doom, and, in another version, a tortoise who kept repeating the message to himself as he moved slowly along was outpaced by a hare who ran so fast that he muddled the message when he arrived. These stories are significant for the under-

[1] Fox, loc. cit., p. 273.
[2] Ibid., p. 274.
[3] Sir James Frazer, *Folk-lore in the Old Testament*, vol. i ch. ii.

standing of primitive ideas in three respects, of which one is here relatively irrelevant. The first message decides destiny: when the plodding, conscientious tortoise delivers the real message it is too late because the reckless hare has already delivered the wrong one. This impossibility of repeal is the irrelevant issue here. The second significance is relevant, for it is the authoritative rôle of the moon. The moon can decree fate for men, though she is subject to the whims and mistakes of her messengers. This is significant, but there is a prior significance in the social status of animals and, since the moon is personified for her rôle of authority, of inanimate objects.

The animal messengers extend the boundaries of human society beyond human beings, for they convey messages and receive hospitality as if they were human. A further extension includes the moon and hints that society as it is understood to-day is a contracted residue of an assemblage of beings that originally included every variety of existence—even stones by the wayside. The inclusion of animals with human beings in a society embracing both is written clearly on primitive annals as they are guaranteed by the practices, beliefs, and legends of uncivilised peoples to-day. Animal actors who are men, or supermen, in animal form, fill folk-lore to overflowing. Primitive men do not agree with Sir Thomas More that " The World was made to be inhabited by Beasts, but studied and contemplated by Man," [1] nor with Descartes that animals have no reason.[2] They are innocent of modern depreciatory distinctions, like Lester F. Ward's " The environment transforms the animal, while man transforms the environment," [3] and would condemn such belittlings of the animal if they understood them. They incline their depreciation towards man, favouring the animal by preferring an animal ancestry. The Delaware Indians who call the rattlesnake their grandfather, the Wakanda of East Africa who reckon the hyæna in their ancestry, the Malagasy who are descended from crocodiles, the Sumatran clansmen who trace their descent to a tiger,[4] and the Iroquois whose clan ancestor was a turtle [5] indulge a widespread primitive preference for non-human ancestors. This estimate is directed by an estimate of animal superiority, for ancestry is associated in the primitive mind with eminence. The deeds of ancestors and the significance of their actions for the destiny of their posterity penetrate primitive legends and rites. The identification of ancestry with eminency and with animal kinship hints at the primitive estimate of the animal asserted by Wundt. There was a period in the history of the human race, in the opinion of this writer, when men systematically thought of the animal as superior in wisdom and power to themselves.[6] Hints of this formerly universal estimate of the animal are scattered through legends and rites of present primitive peoples. In Paraguayan Chaco a beetle was raised to the supreme eminency of creator of the world [7]—a startling commentary on the assertion of Durkheim that the humbler natural objects are the first to be divinised.[8] The Indian who was taught by a black bear to catch salmon and build canoes,[9] the Gold Coast natives who are helped by pythons or crocodiles,[10] and the pagan tribes

[1] Sir Thomas Browne, loc. cit.

[2] Descartes, *Discourse on the Method of Rightly Conducting the Reason and Seeking for Truth in the Sciences*, pt. v.

[3] Lester F. Ward, *Pure Sociology*, pt. i.

[4] Sir James Frazer, loc. cit., vol. i, ch. i.

[5] Durkheim, *The Elementary Forms of the Religious Life* (Swain's trans.).

[6] Wilhelm Wundt, *Elements of Folk Psychology* (Schaub's trans.), Introd.

[7] W. Burbrooke Grubb, *An Unknown People in an Unknown Land.*

[8] Durkheim, loc. cit., bk. i, ch. iii.

[9] Ibid.

[10] Cardinall, loc. cit., pp. 37–9.

of Borneo who have secret animal helpers[1] are a few samples of widely scattered beliefs that disclose the primitive estimate of the animal. This primitive estimate is incarnated in the dragon, who may be regarded as a typical personage of myth in many rôles. The dragon, as he appears in primitive myths, represents the impression of magical power and eminency made by the animal on the primitive mind.

Since primitive society includes animals with men, and since men may have animal ancestries, primitive classification does not divide animate nature by lines which separate men, animals, and plants into three distinct groups. Groups or clans are defined by lines, which, so to speak, cut across these divisions and include in each section a group that comprises a certain set of human beings with some animal or plant species. Plants are less prominent in these totemic divisions than animals, but they frequently occur in them. The species of plant or animal included with any group of human beings in one of these divisions is usually termed by anthropologists the "totem" of the group. The totemic phase of primitive life, which some writers think was a distinct stage of human evolution,[2] is most completely represented to-day among the Australian aborigines. Messrs. Spencer and Gillen, in their two famous books, have described a number of their social systems that are extensively cut up into these totemic divisions. In one tribe, for example, one group of men are "emu men"—they and the emus are classed together in one division, and the men regard the emu as one of themselves. Other animals are, similarly, the totems of other groups, and, less frequently, plants or even inanimate objects are the totems of other men. The relations between human totemic groups and their totems vary, but the essential significance of totemism for the present discussion is its emphasis on the social community between men and animals. The totem tends to be the ancestor of the group, and its relations with its human section of the totemic division to be those of kinship. It tends also to social eminency in the totemic group, in apparent accordance with a primitive tendency to estimate the power and significance of the animal above human power and significance.

In the moon stories previously considered the moon is obviously a member of the social community, and this extension of the social group, through animal and plant, to include inanimate objects is characteristic of primitive life. The primitive distinction between man and animal is not so made as to exclude their social community. The Malagasy who thinks his ancestor was a crocodile or the Australian "emu man" who thinks he and the emu are kinsmen must realise that men are not crocodiles or emus—their eyes guarantee that. But they include men and various animals in groups because, in spite of obvious differences, animals are qualified for society. Inanimate objects may be similarly qualified, though they are as obviously different from men as animals are. Though the personalisation of the moon ascribes to her human qualities it need not imply that she is human—eyes again guarantee that. The essence of the primitive notion is social community between man and inanimate objects, though this social community tends to represent inanimate things as human in character. The belief of one Australian tribe that certain rocks changed into kangaroos hints at a connection between men and stones (for kangaroos might be ancestors of men) that suggests social community between them without implication of personality in the latter. The ancestors of the Australian Diari usually changed into stones when they died.[3] This metamorphosis of stones into animals and of men into stones is allied to the metamorphosis of men into animals or plants, and vice versa, that is so prominent in primitive beliefs

[1] Hose and McDougall, *The Pagan Tribes of Borneo.*

[2] *Vide* Wundt, loc. cit.

[3] *Nature*, February 12, 1920, "Australian Signposts."

and myths. Metamorphosis is so frequently discovered among primitive peoples, it is such a frequent motif of myths, it is so familiar a product of folk-lore in fairy tales (such as "Beauty and the Beast"), and it survives so persistently in superstitions (witches habitually change into cats) that it must spring from some preconception firmly fixed in the human mind. Petrifaction myths in which men or animals change into stones or vice versa are widely dispersed and are an integral part of the belief in metamorphosis. The general significance of metamorphosis is clear—it expresses a sense of social community between man and the whole of his surroundings. This fundamental sense of universal social community is a preconception of the primitive mind, and it directs us to an explanation of the universal belief in a connection between the moon and life in plants, animals, and men. The analogical transfer of decrease or increase from the moon to sympathetically responding objects requires an adequate motive, for association of ideas is not haphazard. The primitive preconception of a universal social community provides a clue and directs us to the source of the belief in lunar control over life and nature. We are thus directed to a psychical centre in the primitive mind, to a psychical source from which many primitive beliefs and practices emerged.

By thinking, said Socrates to Theætetus, "I mean the conversation which the soul holds with herself in considering of anything. I speak of what I scarcely know; but the soul when thinking appears to me to be just talking —asking questions of herself and answering them, affirming and denying."[1] "Talking" appropriately denotes an exchange of ideas among members of a group, and "thinking" the origin of ideas in a single mind. Thus when Socrates compares thinking to talking he involuntarily thinks of himself as a group. This comparison of the self to a group of selves is a spontaneous and inveterate habit. When John and Thomas converse, Oliver Wendell Holmes easily persuades us that six people are talking: the real John, John's ideal John, Thomas's ideal John, John's ideal Thomas, Thomas's ideal Thomas, and the real Thomas.[2] This multiplication of selves comes easily as a metaphor, and in the struggle between the Old Adam and the New often successfully imposes itself as a reality. Because man is so essentially a creation of society and so essentially a social creature he thinks of himself so persistently as one of a group that if he is obviously alone he makes a group of himself. There is the less reason for surprise, therefore, when primitive man is discovered making not only himself, but everything else, including the moon, into a social group. He is so born and bred among human beings, he is so constantly in intercourse with them, he has so unintermittently to respond as if he were addressed by persons or addressing them that he, on the one hand, multiplies himself and, on the other hand, attributes social qualities to everything because he is insensibly impelled to think and act in terms of social intercourse. This fundamental and engrained habit reserved for his posterity two hardly won discoveries. The singleness of the human mind or soul, its essential unity and selfhood, is the counterpart discovery within the man himself, improbable as the parallel may appear, of the discovery in the outer world of nature that the nature of things, and even of living things, excludes them from the human social circle. It is a common remark that "the ancients were generally wanting in the distinct concept of personality,"[3] and that even in Plato, Aristotle, and Plotinus personality is inadequately considered and conceived.[4] This imperfect conception of

[1] Plato, *Theætetus*, 190.

[2] Oliver Wendell Holmes, *The Autocrat of the Breakfast-Table*, iii.

[3] Zeller, *Plato and the Older Academy* (trans. by Alleyne and Goodwin), p. 287.

[4] Idem, *Presocratic Philosophy* (Alleyne's trans.), i, 150.

personality, expressing itself by its imperfect grasp of the unity of the individual mind and by its exaggerated estimate of the social order, derived from the fundamental part played by the intercoursing social group in human experience. The mistakes of primitive thought did not continue to bind the thinking of Plato and his successors, who can be observed in the act of shaking themselves free from them, but the mental habits stamped into the mind by the dominance of the social group over thought and action continued to influence them and still, though in decreasing extent, influence us. These mental habits may be compared to ropes ; they bound the primitive mind tightly ; they hung loosely round Plato so that he could move, though still heavily encumbered ; round the modern mind they are loose enough to permit slightly impeded movement. One modern school of writers characterises primitive beliefs as "collective representations," conceptions (comparable with language) imposed upon individuals, independent of any one of them, transmitted from generation to generation and common to social groups.[1] On this view the group is in effect the thinking unit. So far as it expresses the truth that primitive man is so penetrated by a sense of social intercourse as to think of his relations with everything as if they were social, and like his relations to his fellows, the doctrine of collective representations is illuminating. This, then, is the teeming psychical source of many primitive beliefs and practices, the source of the preconception required to interpret the associations between changing moon and growing things. Man is so surrounded by social intercourse and so accustomed to responding to social influences that he was constrained in the days of his youth to respond to everything, both in thought and deed, as if he were always in society. Even so is the child still tempted to think of things in terms of persons.

Animism, belief in souls or personal beings who may inhabit any object or live a free life, is connected with thinking in terms of social intercourse, but is not its inevitable result. The animism of the human social group, whose members are souls or personal beings, as the social group is extended into the world may dilute down into animatisation. All grades of social qualification, from animism to barely recognisable animatisation, have been ascribed to objects like the moon. Prominent and striking natural objects, like the moon herself, may be thought of as the habitations of great gods or as the abodes of minor spirits or as divine beings in themselves or as animated in greater or less degree. There is no constancy in conception and in any particular myth, such as any of the previous moon stories, and in any particular sympathetic connection between moon and growth it may be difficult, or impossible, to define the exact nature or grade of the moon's social qualifications. How far the moon, at any one time, is an actual humanly conceived person, or how far she is socially qualified, would be usually an anthropological conundrum. But one feature of social intercourse provided a universal and permanent preconception for the primitive estimate of lunar control.

The original laughter of the child, Hartley remarked, is multiplied by imitation, and "whatever can be shown to take place at all in human nature," he adds, "must take place in a much higher degree than according to the original causes, from our great disposition to imitate one another. . . ."[2] This intensive multiplication or induration of habit in single members of society is accompanied by an extensive multiplication or spread of habit through the social group. The *l'âtah* who grimaces or wags his finger in faithful following of his companion[3] and Critias who is driven into a difficulty by the difficulty of Socrates, "as one person when another yawns in his

[1] Cornford, *From Religion to Philosophy*, "Collective Representation."
[2] Priestley, *Hartley's Theory of the Human Mind*, p. 272.
[3] McDougall, *Social Psychology*, "Imitation."

presence catches the infection of yawning from him,"[1] are reminders of the imitative impulses constantly streaming through society. Imitation, whether in its most effective form of unwitting imitation,[2] or as "imitation by approval,"[3] or, widening its definition for present convenience, as a compulsion by general consent or resolve on many individuals or as a submission of many to the will of one, produces in the human group a homogeneity exhibited as an extensive sympathetic response, in which the action of one is constantly repeated throughout the members of the group. This repetition of habit or action, this system of sympathetic responses, impresses on each individual an expectation of like conduct among all the members of his group. The great uniformity or social homogeneity that is usually admitted to characterise primitive communities would intensify this expectancy. This preconception invites an application to the pervasive conviction of sympathetic response in growing things to the phases of the moon. The moon is in society, growing things are in society, men are in society; the same habit will run through them all.

Since imitation tends to be specially definite when the group has a definite leader,[4] and the prominence of the moon in the dark sky endowed her with prestige, it would be natural to assume a special imitative or sympathetic response to her. The assumption would be spontaneous or unwitting and would include any object of special attention, corn, for example, or the locks of Tiberius, in its scope.

The prominence of the moon and her varying phases was, according to the hypothesis propounded here, the originating centre of the doctrine of lunar sympathy. A real increase or decrease in her size, through ignorance of the rôle of reflection of light in her varying aspects, would impress itself upon the primitive mind with all the force of a sensible intuition. A sense of social community, clearly expressed in primitive myth and custom that spontaneously accepted the moon as a member of society, applied a preconception to this spontaneous estimate. The arrestiveness of the moon endowed her with prestige, and a preconceived estimate of imitative or sympathetic responses pervading society fixed on this prominent, mysterious, and constantly changing object as a centre or initiator of such responses. This fundamental notion can be detected in all the varying estimates of the moon, whether she simply, by her own waxing, stimulates the hair of Tiberius or whether she is more personalised in her promise of resurrection to men. The doctrine of lunar sympathy, in short, in all its rich variety of detail, depends firstly upon the sensible impressiveness of the moon, and secondly upon primitive man's inveterate inclusion of all things within his social group.

A net thrown widely enough will catch some fish, and a belief in universal lunar control will light on some truths. There is some degree of connection throughout the universe, and astrology errs through misapplying this fact. The moon does assist in the control of our tides, and Mr. Fox has discovered some "Lunar Periodicity in Living Organisms."[5] A Suez sea-urchin ripens reproductively as the moon waxes and recuperates as it wanes, some marine worms "show a lunar reproductive periodicity," and human menstruation appears to contain "a rhythmic causative factor having the period of the revolution of the moon." These rhythms may be mediate and immediately stimulated by some change more directly produced by the moon—the sea-urchins might be, for example, tidally stimulated, though Fox thinks they

[1] Plato, *Charmides* (Jowett's trans.), 169.
[2] Rivers, *Instinct and the Unconscious*, p. 92.
[3] Reid, *Essays on the Active Powers of Man*, Essay 3.
[4] Rivers, loc. cit., p. 90.
[5] Fox, loc. cit.

are not. Some flowering plants turn to the moon as others turn to the sun, and eels will apparently not migrate against the moon's rays. On the other hand, Fox found that moonlight had no effect on the growth of melons, marrows, and other fruits. The modern Egyptian belief in this effect is thus a remnant of an old superstition. The moon is our near neighbour and able to influence us, but the primitive estimate of this influence was exaggerated by uncritical preconceptions. The vast primitive guess that anything might respond to the moon's phases does contain, however, some guesses that can be verified.

Inanimate things, since they too had social qualifications, were often supposed to be influenced by lunar sympathy. It may be presumed, though the unexpected may happen, that modern science will not discover any increase in stocks or stones corresponding to the waxing of the moon.

# REVIEWS

## MATHEMATICS

**Principles of Geometry.** By H. F. Baker, Sc.D., F.R.S. Vol. I. Foundations. [Pp. xi + 182.] Vol. II. Plane Geometry, Conics, Circles, Non-Euclidean Geometry. [Pp. xv + 243.] (Cambridge: at the University Press, 1922. Price, Vol. I, 12*s.* net; Vol. II, 15*s.* net.)

These two volumes are the first of a series which seeks to introduce the reader to those parts of geometry which precede the theory of higher plane curves and of irrational surfaces, and their importance cannot, I think, be over-estimated. Prof. Baker believes that the long preliminary study of elementary geometry to which at present so much time is devoted can largely be avoided, and that after an extensive study of diagrams and models the student may straightway enter upon a course such as is described in this book, and learn at once general principles, which, with a moderate demand on the memory, give an immense command of detail. He will learn, what seems to be deliberately concealed by most English textbooks, that projective geometry need not—and indeed cannot without losing its essential feature—be based upon metrical geometry; he will learn the indispensable ideas of geometry of more than three dimensions and of the geometry of so-called imaginary points. His path will, I fear, not be an easy one, but it will be secure, it will afford magnificent views of the country traversed, and will be, in short, delightful.

Vol. I deals with the necessary logical preliminaries, rejecting the consideration of distance and of congruence as fundamental ideas and replacing them by a theory of related ranges. The first chapter, Abstract Geometry, begins with a statement of the Propositions of Incidence, the laws of combination of the entities called by the names *point*, *line*, and *plane*; Desargues' theorem and the construction for the fourth harmonic point are deduced, and the theorem that a chain of perspectivities can be reduced to two links. It is next shown that the Propositions of Incidence alone do not suffice to secure that the correspondence of the points of two related ranges is unique when three points of the one are given as corresponding to three points of the other; but that this result will follow from the assumption of Pappus' theorem concerning the collinearity of the intersections of the cross-joins of three points on each of two intersecting straight lines. The last section of the chapter introduces an algebraic symbolism which represents the Propositions of Incidence, and it is shown that the introduction of the Pappus theorem corresponds to a definite limiting law of combination of the symbols, namely, that their multiplication is commutative.

The point of view adopted in this chapter is general and abstract; for example, the word "line" is used in such a sense that every two straight lines of a plane intersect one another; also the adoption of Pappus' theorem may appear artificial. Further, it takes no account of two notions which seem to be inseparably bound up with our conception of space as derived from experience, the notion of accessible as distinct from inaccessible points, and the notion of the order of a set of points upon a line. The second chapter, Real Geometry, is therefore interpolated to examine more concretely our fundamental conceptions. It is required that all constructions made shall use only accessible points, so that assumptions are needed as to what points are accessible when others are known to be so, *e.g.* for points on a line, the notion of "betweenness." This Real Geometry is then generalised by the introduction of *postulated points*, and it follows that we may regard the space of the Real Geometry as part of a space in which the Propositions of Incidence are completely valid, provided that postulated points, lines, and planes are allowed an existence, whether they be accessible or not. Section III of this chapter deduces Pappus' theorem for the case of the Real Geometry amplified in this way, from the notion of an abstract order among the points of a line, involving a definite assumption as to the points existing on a line.

Chapter III resumes the Abstract Geometry of Chapter I and establishes, in extension of the theory of related ranges, a theory of related spaces of any number of dimensions. The algebraic symbolism then suggests a way of generalising further the abstract geometry by the introduction of imaginary elements; we assign to the geometry such points that when $O + cU$ is a point there is also a point $O + zU$ in which $z^2 = c$. It is shown that a geometrical fact corresponding to this is that it is possible to inscribe in a triangle another triangle whose sides pass through given points. The chapter concludes with the replacement of imaginary elements by a series of real elements, a modification of the theory of von Staudt.

The subject-matter of Vol. II is more familiar and may be dealt with more briefly. The fundamental properties of conics are established synthetically; they are then considered, still without assuming any notions of distance or congruence, in relation to two absolute points, giving propositions which, expressed in the terms current in metrical geometry, concern circles, confocal conics, and so on. Co-ordinates are then introduced by means of the algebraic symbolism of Vol. I and are applied in a number of ways, to extensions of Feuerbach's theorem, to apolar triads, to the consideration of the invariants of two conics. All this is familiar ground, indeed, but anyone who has heard Prof. Baker lecture on elementary conics will confidently expect to be inspired with new ideas and points of view by reading these chapters, and he will not be disappointed.

The last chapter deals with the theory of measurement, of length and angle, by means of an absolute conic, and shows how the so-called non-Euclidean geometries may be regarded as included in the general formulation. A couple of appendices describe certain configurations leading up to the complete figure for Pascal's theorem, which is best considered in four dimensions. There is a page of remarks and corrections to the first volume. It is unnecessary to praise the printing and general production of a book published by the Cambridge University Press; we have heard a criticism of the type used in lettering the diagrams, but the latter themselves are uniformly excellent, and having ourselves tried in vain to get a picture of the fifteen lines of the Pascal figure, we can but gaze in awe and admiration at the wonderfully clear and simple figure of the Hexagrammum Mysticum which forms the frontispiece to the second volume. F. P. W.

**Multilinear Functions of Direction and their Uses in Differential Geometry.** By E. H. Neville. [Pp. 80.] (Cambridge: at the University Press, 1921. Price 8*s*. 6*d*. net.)

An important problem in elementary differential geometry is to associate the curvatures and torsions of curves on a surface with the form of the surface itself; it is a problem which may be investigated by means of "moving axes." This book extends and develops this method out of all recognition. The functions considered are primarily not functions of a single variable direction, but functions of several independent directions. By relating these originally independent directions we obtain functions of a single direction; and a large number of elementary theorems of differential geometry become co-ordinated and expressed by means of properties of a few simple functions. Of these we may mention the *bilinear curvature*, which depends on two tangential directions and reduces to normal curvature when these directions coincide; and the *Codazzi function*, depending on three directions and reducing to the cubic function of Laguerre when they coincide; it is so called because the equations of Codazzi can be interpreted as asserting that it is a symmetrical function. The theory is used to prove the relations between the cubic functions of Laguerre and Darboux, and to obtain formulæ for the twist of a family of surfaces and for the rates of change of the two principal curvatures of a variable member of a family of surfaces along an orthogonal trajectory.

Prof. Neville has a faculty for inventing new names and symbols as well as new methods; his book, in consequence, is terribly difficult to read. Is it necessary to introduce, not only an inverted *kappa*, but also inverted affixes? The decimal notation for paragraphs and equations may be theoretically desirable, but if carried too far gives a repulsive appearance to the page and leads to such absurdities as:

"4.11. That

"4.111. The bilinear curvature is a bilinear function . . . is obvious. . . ."

Or:

"4.12. Dupin's theorem, that

"4.121. At any ordinary point of a surface the sum of the normal curvatures in two directions at right angle is a constant, is shown by 2.321 to be a case of 1.824."

F. P. W.

**Méthodes et Problèmes de Théorie des Fonctions.** Par E. Borel. (Pp. ix + 148.] (Paris: Gauthier-Villars et Cie., 1922. Price frs. 12.)

When M. Borel undertook twenty-five years ago the editorship of the well-known series of monographs on the theory of functions it was with the idea of writing eventually a treatise on the subject. This he has not managed to do, and now, publishing the twenty-sixth volume, the ninth written by himself, he recognises that he will never do it. "Je laisse donc à de plus jeunes le soin d'écrire ce Traité, dont l'heure viendra bientôt. La théorie des fonctions a toujours été, d'ailleurs, une science de jeunes, et il est probable qu'elle la restera, car les qualités d'imagination abstraite qu'elle exige paraissent être le privilège de la jeunesse, tandis que les parties des mathématiques qui touchent aux applications exigent peut-être plus de maturité d'esprit. Cet Ouvrage . . . sera donc vraisemblablement mon dernier livre de théorie des fonctions."

The contents of the book are thus miscellaneous, and consist, for the most part, of reprints of notes and memoirs which have not found a place in the author's previous books, but which he thinks may be the starting-point of new investigations. They deal with the theory of aggregates, with the study of the simple operations which can be performed on functions and which serve to define or to create them, with the theory of the growth of functions and the part played by arbitrary constants. With this reproduction of earlier work goes a running commentary, in which the author constantly recurs to a somewhat fanciful analogy between the theory of functions and biology. Under the impulse of necessity and of natural curiosity man has extended his biological knowledge beyond the rudiments which are indispensable for agriculture; he has catalogued and classified more and more species, he has tried to perfect the species which he uses and to create new varieties, he has studied the normal and pathological behaviour of the different species, and come to examine more and more deeply their fundamental element, the cell. Similarly, the theory of functions has developed both in extent and in depth; more and more different functions have been investigated and, at the same time, known functions have been dissected more and more carefully so as to learn something of their essence, the real variable.

Another matter which is continually in the author's mind is his disagreement with the point of view of the mathematicians, such as Lebesgue and Denjoy, who insist too much upon generality, who wish to discover propositions which shall be true, not only of all functions that have been constructed, but of all functions that ever will be. As he points out, the discovery of continuous functions without derivatives does not prevent the study of continuous functions which have derivatives from playing an important part in analysis. One will probably agree with him in not being much concerned with functions which would require an infinite number of words for their definition.

F. P. W.

**Théorie des Nombres.** Par M. Kraïtchik. [Pp. ix + 230.] (Paris: Gauthier-Villars et Cie., 1922. Price frs. 25.)

The object of this work is the actual solution of congruences; it is not concerned with general theory. The author has invented graphical and mechanical methods which enable the processes of groping or sifting (tâtonnement ou criblage) to be carried on systematically and with a certain facility; he prints 60 pages of numerical tables of linear factors of quadratic forms, of factors of $2^n \pm 1$, and of the squares of numbers less than a million; the type of these might certainly be better. There is an interesting introduction by M. d'Ocagne, the creator of the science of Nomography.

F. P. W.

## ASTRONOMY

**Sidelights on Relativity.** By Albert Einstein, Ph.D. Translated by G. B. Jeffery, D.Sc., and W. Perrett, Ph.D. [Pp. 56.] (London: Methuen & Co., 1922. Price 3*s*. 6*d*. net.)

The translations of two addresses by Einstein are given in this small volume. The first, entitled "Ether and the Theory of Relativity," was delivered on May 5, 1920, in the University of Leyden. With the development of the theory of relativity, previous conceptions of the ether had of necessity to be modified. One school of thought was for abandoning the conception entirely; another considered it necessary to retain it. Here we have Einstein's own views; a few quotations may summarise these. "The ether of the general theory of relativity is a medium which is itself devoid of *all* mechanical and kinematical qualities, but helps to determine mechanical (and electromagnetic) events." The gravitational and electromagnetic fields are distinguished: "There can be no space nor any part of space without gravitational potentials: for these confer upon space its metrical qualities without which it cannot be imagined at all. The existence of the gravitational field is inseparably bound up with the existence of space. On the other hand, a part of space may very well be imagined without an electromagnetic field." Hence "our present view of the universe presents two realities which are completely separated from each other conceptionally, although connected causally, namely, gravitational ether and electromagnetic field, or—as they might also be called—space and matter."

The second address, "Geometry and Experience," was delivered before the Prussian Academy of Science on January 27, 1921. It deals with the fundamental conceptions on the basis of geometry, the meaning of non-Euclidean geometry, and the question as to whether the universe is spatially finite or infinite.

H. S. J.

**The Telescope.** By Louis Bell, Ph.D., Consulting Engineer; Fellow, American Academy of Arts and Sciences. [Pp. ix + 287, with frontispiece and 190 figures.] (London: McGraw-Hill Publishing Co., 1922.)

This volume forms a welcome addition to astronomical literature, and will be particularly appreciated by amateurs who possess or are thinking of possessing a telescope of their own. Although there is an extensive literature dealing with the subjects treated by Dr. Bell, it is for the most part scattered and not easily accessible to the average amateur observer. Not only does the book provide interesting reading, but also it contains numerous practical hints which will prove of value to the user of a telescope.

The first chapter on the evolution of the telescope gives a concise and interesting account of the historical development of the telescope up to the time of the Herschels, from which time the modern telescope may be said to date. The second chapter is concerned with this phase of the subject. The author then deals with optical glass and its working, the properties of objectives and mirrors, mountings, eyepieces, hand-telescopes and accessories. A chapter is devoted to the testing and care of telescopes, in which are given —amongst other things—details of how to test the quality and adjustment of an objective and of the best methods of silvering. Another chapter deals with the setting up and housing the telescope, including particulars of the adjustments required and how to perform them. The last chapter is on seeing and magnification, and is particularly well written, containing just the information which the amateur requires under these headings.

There are a few points on which comment may be made. On p. 55, in discussing the relative advantages of refractors and reflectors, it is stated that "the reflector as ordinarily proportioned is at a disadvantage, chiefly because it works at F/5 or F/6 instead of at F/15." The statement should surely be inverted: for observation of faint extended objects a large aperture ratio is necessary, and it is a distinct advantage of the reflector that it permits of aperture ratios impossible of attainment in the case of a refractor.

On p. 190 the statement, in reference to the diffraction grating, that "the spaces between the furrows reflect brilliantly and produce diffraction spectra," is very misleading. In dealing with adjustments in Chapter X, the methods described are of no use for observers near the equator, and alternative methods suitable for equatorial latitudes should be given. On p. 261, the fact that double stars can be resolved beyond Rayleigh's theoretical limit is taken as showing that "the visible diameter of the central disc is in effect less than the diameter indicated by the diffraction pattern." The correct explanation is that Rayleigh's criterion is based upon an arbitrary assumption which is equivalent to specifying the minimum contrast which the eye can detect. Actually, under favourable conditions a much smaller contrast can be detected. On p. 149, the micro-telescope is stated to be a compact and powerful instrument. The reviewer has looked through many hundreds of these without finding one which could be called even decently good from an optical point of view.

Particular attention may be drawn to the following paragraph from p. 273: "With respect to magnifying powers . . . the lowest power which discloses to the eye the detail within the reach of the resolving power of the objective is the most satisfactory." This fact is so often overlooked by amateurs, that it is well to have it stated so explicitly, and for the same reason it is repeated here. H. S. J.

**General Astronomy.** By H. Spencer Jones, M.A., B.Sc. [Pp. viii + 392, with 24 plates and 103 illustrations.] (London: Edward Arnold, 1922. Price 21s. net.)

Very few good general textbooks of Astronomy have been written in the English language, and among the best of those that exist none has been published or revised recently enough to embody the many important results and theories which have marked the strikingly rapid advances of this science within recent years. English students are therefore under a double debt of gratitude to Mr. Jones for the delightfully readable and up-to-date work which he has written under the above title. It is equally valuable as an introduction to astronomy for first-year students, or for the general reader who wishes to be *au fait* with the latest researches. All the numerous branches of the subject are dealt with, though none but the most elementary mathematics are employed, so that it is scarcely to be expected that any considerable amount of detail would be included. Nothing of great importance, however, has been omitted, and it is surprising how much has been compressed into one volume without loss of clarity.

The avoidance of mathematics renders the treatment of spherical and dynamical questions rather difficult. The usual lines are followed, for the most part, in these sections, and some problems (such, for example, as the inequalities of the lunar motion) are explained with admirable clearness to the non-mathematical reader. A paragraph is also included on latitude variation which is not usually to be found in works of this class.

The author is rather inclined to be dogmatic on some points which at present may still be regarded as open questions. For example, the conception of the moon as a "dead" world showing no evidence of change is strongly opposed by several astronomers; the distances of stellar clusters as found by Shapley are also not yet universally accepted. Several mistakes occur throughout the book, but are not, in general, of very great importance and will doubtless be rectified in a later edition. It may be of use to mention here a few of the more misleading examples. On p. 285 "Betelgeuse" should read "Arcturus"; in the table on p. 313 the spectral type of Procyon should be $F_5$; the majority of the cluster variables have shorter, not longer periods than the original cepheids (see p. 343); S Persei (for Algol, on p. 345) should be $\beta$ Persei.

Perhaps the most interesting portion of the book is that contained in the last three chapters, in which are described all the most important recent developments in sidereal astronomy. In addition to the usual material, prominence is given to the measurement of angular diameters of stars, Adams' spectroscopic method of parallax determination, star streaming, and other statistical investigations, ionisation in stellar atmospheres, Eddington's researches on the interior of stars, recent cosmogonic theories, and other important questions of present-day astronomy. There appears, however, to be no description of the calculation of parallaxes from group motion among stars, which is an accurate and in many cases extremely important method of deriving stellar distances. The apex of the sun's way is superior to the intersection of the equator and galaxy as an origin for galactic longitudes. Its use is strongly advocated by some astronomers, and might have been referred to, since it abolishes the effects of precession. Mention might also have been made of Lockyer's theories in connection with stellar evolution and spectral type, which in essence were similar to those of Russel though reached independently.

The diagrams and illustrations are both excellent and well chosen throughout. The 24 beautiful plates add greatly to the value and charm of an interesting and well-written textbook.

D. L. E.

**The Elements of Astronomy.** By D. N. Mallik, B.A., Sc.D., F.R.S.E., Professor, Presidency College, Calcutta. [Pp. 8 + 233, with 109 diagrams.] (Cambridge: at the University Press, 1921. Price 14s. net.)

The publisher's notice on the wrapper of this book states that "The author's object has been to give a brief and clear account of those portions of Astronomy which can be dealt with, with the help of elementary mathematics. In the selection of subject-matter and its treatment, he has been guided by his experience as a teacher of Astronomy, so that the book should be found to meet the requirements of students by stimulating thought and ensuring scientific accuracy." A perusal of the book does not confirm these statements. Not only are there many inaccuracies and loose statements, but the style is tortuous and involved. The following extract from the first page may be quoted as an example:

"One was almost implicitly impelled to follow the path, traced on the sky, by the sun, the moon and the stars, from day to day, one was perforce led to note the position of the horizon, where the earth and the sky appeared to meet and the points in it,—by a reference to terrestrial objects,—where the heavenly bodies appeared and disappeared and appeared again in their sojourn, according to almost an immutable law,—if supremely, most impressively inscrutable, as it is even now, in the main."

The author has a fondness for commas which is very irritating. For example:

"That being so, as the earth goes round the sun, and the moon, round the earth, it will, sometimes, happen that the moon, coming between the sun and the earth, will cut off the sun's light—partially or wholly."

English such as this is not conducive to stimulate thought or to ensure accuracy!

It is not possible within the limits of a review to draw attention to all the errors noted in reading the book. It will suffice to refer to a few of them. On p. 201 a proof is advanced of the constancy of the sidereal day as an interval of time. The proof is that the interval between the successive passages of the same star across the meridian, as measured by a clock, is always the same! A little farther on it is admitted that "no clock can always keep correct time." On p. 129 we are told that Venus does not present to the naked eye any appreciable variation in brightness. On p. 144 it is stated that "there is reason to believe that they [comets] are white-hot masses of gas highly attenuated, increasing in brilliance, as they approach the sun, on account of increased velocity." It is also stated that in some few cases the paths of comets are hyperbolas. This is not correct. There is not at present any well-authenticated case of a hyperbolic orbit. But if we were to accept the author's statement, why does "the fact that the paths of comets are conic sections indicate that they belong to the solar system"? (p.145). A body with a hyperbolic orbit cannot very well do so. On p. 141 we are told that Jupiter has four satellites and that Saturn has eight. Although the ninth and tenth satellites of Saturn are comparatively recent discoveries, the fifth of the nine satellites of Jupiter was discovered as long ago as 1892, so that the author is somewhat out of date. What information is conveyed by the following extract from p. 141: "The most striking facts about them [*i.e.* Mercury and Venus] are their transits across the sun's disc, that of Mars being necessarily less so than that of Venus"? A transit of Mars would certainly be a striking sight! On p. 102 the distance of the moon is given as 23,800 miles, and on p. 182 there are two references to Aldeberran (*sic*).

Many more examples of errors, misprints, and loose statements might be quoted, but the above will suffice to show that the last claim which can be made for the book is that of accuracy. It is not a book which we can recommend.

H. S. J.

## METEOROLOGY

**The Rainfall of the British Isles.** By M. de Carle S. Salter. [Pp. xiii + 295, with 80 figures.] (London: University of London Press, 1921. Price 8*s*. 6*d*. net.)

The plan of isolating for study a single meteorological element is one that has great drawbacks, particularly when that element is as intimately connected with others as is the case with rainfall. As Mr. Salter points out in his introductory chapter, the study of rainfall should proceed hand-in-hand with that of the wider subject of geophysics, of which it forms a fragment. Unfortunately, the splendid network of 5,000 rain-observing stations that, together with Mr. Salter's staff at headquarters, constitute the British Rainfall Organisation, cannot at present be backed up by a similar network of observatories fully equipped for a study of the physical state of the atmosphere both near the ground and at great heights. It is for this reason only natural that Mr. Salter's thorough treatment of the incidence of rainfall, though yielding results of the greatest practical importance to engineers, farmers, and some other sections of the community, is in the main simply a statistical treatment and sometimes disappointing from the geophysical point of view. The book begins with a brief—perhaps a too brief—chapter on the physical processes underlying the formation of rain, and passes on to a detailed explanation of the methods adopted in this country for measuring and mapping the amount of rain that falls. Succeeding chapters deal with such subjects as the diurnal, seasonal, and annual variations of rainfall and its regional distribution. Of these the last, which treats of the relation of rainfall to altitude above sea-level and local configuration of the ground, is of particular interest and very instructive, but some of the earlier ones deserve mention too, in particular those which discuss the proportion of rain which, in various places and at different seasons, must be attributed respectively to orographical and cyclonic influences, and to convectional showers of the thunderstorm type. The final chapter deals with problems connected with evaporation and percolation.

E. V. N.

## PHYSICS

**Atomic Theories.** By F. H. LORING. [Pp. ix + 218, with 66 figures.] (London: Methuen & Co. Price 12*s.* 6*d.* net.)

THE author states that his aim is to give the leading facts and theories which relate to the Atom.

The book is certainly a compilation of an abundance of facts concerning atomic weights, isotopes, electrons, nuclei, X-ray and optical spectra and radio-active phenomena. It furthermore contains outlines of the Rutherford-Bohr model; the Lewis-Langmuir model, the octet theory of valence and the quantum theory. The writer feels that the treatment is rather disjointed and doubts whether long quotations and descriptions from original papers constitute a suitable substitute for an exposition in his own words by an author who has absorbed his material from many sources and presents them in some unified form of his own making. This is not to deny that the book will prove useful to those who, through lack of time, may find it impossible to consult not merely the original papers, but even the separate books now available on the matters dealt with in the various chapters of this work. In short, the book, considered as a " textbook," has the advantages as well as the disadvantages of that particular type of literature.

J. R.

**Atomic Form,** with special reference to the Configuration of the Carbon Atom. By EDWARD E. PRICE. [Pp. viii + 140, with 64 figures and an Appendix.] (London: Longmans, Green & Co. Price 5*s.* net.)

THOUGH this book is small, the author has unconsciously contrived to make it so humorous that we have no hesitation in recommending it, if only on that account, as a refreshing diversion from the cares of modern physics and chemistry. The hard-won facts of atomic physics and crystal-analysis are lightly dismissed from serious consideration, and we are asked to nail down all the properties of all the elements to simply the geometrical form of *practically solid* atoms !

Briefly, the argument is that the facts of crystallisation point to " differences of *form* as the most natural explanation of this great diversity of character " among the elements, since the electronic " conception of atomic structure appears to be at variance with our knowledge of crystal structure, and fails to assist us with the many problems of organic chemistry by which we are still confronted." To the element carbon, with the structure of the compounds of which the book mainly deals, the author has assigned the form of an irregular tetrahedron of special dimensions (the carbonoid), and from such a fundamental unit he has arrived at models to represent many well-known organic compounds. But in spite of the ingenuity displayed in the construction of these models—and it cannot be denied that they have been built up with much care and are beautifully reproduced in the figures—it must be confessed that many of the arguments on which they are founded are deplorable. If there is one thing in this world "at variance with our knowledge of crystal-structure," surely the author has hit upon it in his theory of atomic form. We cannot believe that he has ever seriously considered the long-established treatment of geometrical crystallography or the recent analyses of well-known crystal-structures which have been accomplished by the method of X-rays. Otherwise he would never have allowed himself to write : " The simplest form of the Diamond is a tetrahedron, not the irregular tetrahedron of the carbonoid, but one that could be used for either an octahedron or a cube ; the base is an equilateral triangle, and the three other sides are right-angled triangles " : or, " Can a space-lattice be built up to correspond with the structure of the Diamond ? This can be done, but the number of carbonoids employed is so enormous that we have been compelled to resort to the use of hexagonal cards to represent the Benzene nucleus." But the book is full of similar statements.

May we point out to the author that Bragg's analysis of the diamond structure has shown conclusively that the carbon atom does *not* resemble the carbonoid but possesses a trigonal axis, and that the fact that benzene crystallises in the orthorhombic system with two molecules per cell is almost final evidence that, in crystals at least, the benzene ring does *not* possess hexagonal but only a fourfold symmetry at most ?

In the words of the author, " much difficulty and uncertainty surrounds the theory of Atomic Form when applied to other elements," and " any attempt to apply the Theory of Atomic Form to the elements generally brings us face to face with problems of some difficulty."

W. T. A.

**The Origin of Spectra.** By PAUL D. FOOTE and F. L. MOHLER. [Pp. 250, with 46 figures.] (New York : The Chemical Catalogue Company, 1922. Price $4.50.)

ALL students of spectroscopy are aware that in the last few years a great deal of important work on ionisation and resonance potentials has been carried out, but many will owe to this book a full realisation of the extent and significance of these investigations. From the reputation of the authors in this field one would have anticipated no less, but actually they have achieved much more than a summary of researches of this kind. In fact, the treatment of the subject is nearly as broad and comprehensive as the title would lead one to expect, and the authors give us so much that is new and suggestive that their apology for the omission of band spectra and Zeeman and Stark effects from their programme will be very readily accepted.

Chapter I contains a very useful summary of the present position of the quantum theory of spectroscopy. In several respects this is an advance on previous accounts of a similar character, but special attention should be directed to the discussion on series notations, where a very clear statement is given of the points of difference between Paschen's revised notation and that employed by Fowler in his *Report on Series in Line Spectra*. The need for a standard system of notation is becoming urgent; it is therefore particularly unfortunate that these new and authoritative systems should have several serious points of difference. It would seem that the time is almost ripe for an international discussion on this question, when it would probably be found possible to incorporate in one system the best features of both.

After a brief exposition of "energy diagrams" the subject of ionisation and resonance potentials is dealt with, and here it is somewhat disappointing, especially in view of the authors' wide experience in these matters, to find no account of the experimental methods employed in this difficult but fascinating field. Next follows a very valuable chapter on line absorption spectra, in the course of which there is a discussion of some highly interesting results in connection with the determination of "$\tau$," the average time of sojourn of an electron in an outer orbit. Here is probably a line of advance which may lead far. The chapter on thermal excitation and correlation of spectral phenomena with temperature is a very striking one, and contains an adequate summary of Saha's astrophysical work, the details of which are perhaps less familiar to physicists than they should be. The account of X-ray spectra is particularly clear, and will go far towards dispelling the bewilderment which the present nomenclature is apt to inspire in those who have no specialised knowledge of this region of the spectrum.

Appendix I contains a chart from which may be read off approximate values of such quantities as electron velocities and wave-lengths radiated (for a given accelerating voltage) and so forth. Comparatively few, perhaps, will make use of this, but those who do are likely to find it invaluable. Appendix II consists of a ten-page summary of Bohr's recent lengthy paper (*Zeitschrift f. Phys.*) setting forth his new theory of atomic structure.

References to original papers are numerous and are brought right up to date, and there are a number of very excellent plates.

W. E. C.

## CHEMISTRY

**An Inorganic Chemistry.** By H. G. Denham, M.A., D.Sc., Ph.D., Professor of Chemistry, University of Capetown. [Pp. viii + 684. Illustrated.] (London: Edward Arnold & Co., 1922. Price 12*s.* 6*d.* net.)

It is pleasant in these days of high-priced books to welcome a textbook on chemistry at a moderate price, and although one swallow does not make a summer it may be reasonably regarded as an omen of better times to come.

Prof. Denham has given special prominence to the Periodic System in his book. After considering the reactions of the halogen and oxygen families of elements, the Periodic System is carefully dealt with and made the basis for the study of the remaining elements.

The ionic theory is not discussed until the non-metals have been dealt with, and in this way the electrolytic theory of solution forms a useful introduction to the study of the metals and their salts.

The book is clearly and concisely written, but is not overloaded with details of unimportant substances and other side-issues, and affords a useful introductory textbook on inorganic and general chemistry for students, and especially for those studying other branches of natural science who need a complete and thorough grounding in the fundamentals of chemical science.

F. A. M.

(1) **Synthetic Colouring Matters. Dyestuffs derived from Pyridine, Quinoline, Acridine, and Xanthene.** (Monographs on Industrial Chemistry.) By J. T. Hewitt, M.A., D.Sc., F.R.S., Emeritus Professor in the East London College. [Pp. xi + 405.] (London: Longmans, Green & Co., 1922. Price 14*s*. net.)

(2) **The Manufacture of Dyes.** By (the late) John Cannel Cain, D.Sc. [Pp. ix + 274.] (London: Macmillan & Co., 1922. Price 12*s*. 6*d*. net.)

(1) It is a healthy sign that the British dye industry is slowly but surely producing a literature of its own, and Sir Edward Thorpe is to be congratulated on having arranged for the production of some half-dozen monographs covering the various groups of dyes, the present volume by Prof. Hewitt being the first of this section of the "Monographs on Industrial Chemistry."

Hitherto there has been no class of works between the various general textbooks on dyes, which necessarily cannot deal in great detail with the different groups of dyes, and such massive productions as Winther and Friedländer, which cover chiefly the patent literature.

For this reason Prof. Hewitt's summary of our present-day knowledge of the dyes of the pyridine, quinoline, acridine, and xanthene dyes is very welcome, and will be read with great interest by all those who work with these classes of colouring matters.

The growth of the subject is indicated by the fact that it was originally intended to include the acridines, xanthenes, azines, and oxazines in one volume, but it was soon found to be necessary to write two books, the oxazines and azines in one and the xanthenes and acridines in the other, and to include in the latter a chapter on the important work which has been done lately, chiefly at Cambridge, on the sensitising dyes of the quinoline series, and thus providing an excellent summary of the present state of our knowledge of this group.

The chief objection that may be lodged against the work is that the extracts from patents are too long and detailed; the general results claimed in any given patent where several examples are quoted could best be given in tabular form, whilst the actual quantities given could well be omitted; as the author truly says, "a specification does not always contain the whole truth and nothing but the truth."

There are a certain number of misprints such as "Ehtmyl" for "Methyl" on p. 201, "quionline" for "quinoline" on p. 54, whilst the formula for butanol on p. 54 is incorrect.

These, however, are minor points, and may well be disregarded in passing judgment upon this valuable contribution to chemical literature.

(2) It is somewhat difficult to criticise a posthumous work by one who was so recently amongst us, without knowing just what was intended, and as Prof. J. F. Thorpe points out in his preface, it has been printed practically as it was left, so that many matters which might otherwise have been revised by the author have remained as they were.

It is fairly obvious that Dr. Cain intended the book to be a supplement to his earlier volume, *The Manufacture of Intermediate Products for Dyes*, and the general style of the book is similar to that volume.

The work is, of course, largely a réchauffé of recipes and patents from elsewhere, though it is none the less useful on that account, as an examination of its pages will often save a good deal of work in looking up references.

It is evident, however, that the book in its present incomplete form is only an outline of the finished work which Dr. Cain no doubt had in mind, and there is a certain air of sketchiness and lack of detail in many parts which shows that it was intended to expand these pages before publication. Many of the paragraphs on azo dyes, for instance, are so short and lacking in all detail as to be valueless. The two pages devoted to indigoid and thioindigoid dyes are quite inadequate for dealing with this most important class of dyes, and again the section on anthraquinone dyes completely omits all reference to the highly important group of the Algol colours.

In the circumstances it might have been better to have delayed publication for awhile until the manuscript had been revised and completed; perhaps such a revision may be possible before the issue of the next edition.

Nevertheless, in spite of these drawbacks, the book contains much that is of value to dye chemists, and will no doubt be of assistance to those who have to deal with the manufacture of colouring matters.

F. A. MASON.

**A Treatise on Chemistry,** Vol. I. the Non-metallic Elements. By the RT. HON. SIR H. E. ROSCOE, F.R.S., and C. SCHORLEMMER, F.R.S. Fifth Edition, revised by Dr. J. C. CAIN. [Pp. xv + 968, with 226 illustrations and a portrait of John Dalton.] (London: Macmillan & Co., 1920. Price 30s. net.)

ROSCOE and Schorlemmer's treatise is such a classic that it is almost as difficult to find anything fresh to say about it as it would be to offer a personal criticism of an old friend.

Since the appearance of the fourth edition of the work chemistry has suffered a severe loss by the death of Sir Henry Roscoe, and it is a fortunate matter that Dr. Cain was already associated with the author in the earlier edition of the book, so that he has been able to preserve its general character and style.

The endeavour has been made to bring the book up to date by inserting references to recent work, but one is rather left with the impression that it is a case of trying to put new wine in old bottles.

When, for instance, as on p. 427, we find work published in 1899 referred to as "recent," one cannot help feeling that the book really requires a fundamental rearrangement and rewriting rather than a mere revision unless it is to remain simply a readable history of twentieth century chemistry.

Many of the illustrations, also, are a trifle too archaic to be convincing, and would be all the better for a drastic revision.

It is somewhat remarkable that the immense Louisiana sulphur deposits are dismissed in a line; also, having regard to the scientific and technical importance of the synthetic production of ammonia and its oxidation to nitric acid, justice has hardly been done to these subjects by the space allotted to them.

Again, it would be interesting to know how many sulphuric acid works continue to employ platinum stills for concentrating their acids, as stated on p. 428, with platinum at £40 an ounce! There does not appear to be any mention of the use of fused quartz for the purpose, or of acid-resistant iron.

Probably what is wanted is a group of chemists working under Dr. Cain's direction to assist him with the very laborious work entailed in revising such a book, so that the less important details may be removed to give place for more modern matter, otherwise there is considerable danger of the educational value of the book being diminished by the retention of subjects which are rapidly becoming merely of historical interest.

The printing and general arrangement of the treatise continue, as might be expected, to be a model for chemical publications, though the purpose of the uncut pages is not very clear; they are more favoured by the bibliophile than by the chemist.

The fact that the book has reached its fifth large edition is a proof that there is always a demand for a really readable and reliable textbook of inorganic chemistry, and chemists owe their thanks to Dr. Cain for having supervised the issuing of the present edition.

F. A. M.

**The Properties of Electrically Conducting Systems.** Including Electrolytes and Metals. By CHARLES A. KRAUS, Professor of Chemistry in Clark University. [Pp. 415, with 70 figures in the text.] (New York: The Chemical Catalog Co. Inc. Price $4.50.)

THE problem of reducing the experimental material on electrically conducting systems to the form of a readable treatise has been successfully solved by the writer of this book. The enormous expenditure of energy in this field has produced tables of figures, and curves without number, but has not brought out any simplifying assumption comparable in value with that of the simple Arrhenius theory. This has made the task of correlation exceedingly difficult.

In this book, the author emphasises one of the main causes of the slow rate of development of the theory of electrolytic solutions. The neglect of non-aqueous solutions in the recent theories of ionisation has been a serious handicap to successful effort. Modern theory has largely ignored the astonishing variety of the conductivity curves of electrolytes in non-aqueous solvents, and confined itself to the study of aqueous solutions. The numerous diagrams and tables of data given in the present treatise should serve the useful purpose of directing the attention of chemists to this aspect of the problem.

Perhaps the most interesting chapters are those which deal with the modern theories of electrolytic solution, and of the ionisation of metals in liquid ammonia. The latter, based chiefly on the work of the author and his collaborators, is especially valuable, since the metals in ammonia give rise to electrical systems intermediate between metallic and electrolytic conductors. The part played in these solutions by a new type of anion, composed of an electron associated with solvent molecules, is a discovery of the author. The chapter included on the properties of metallic substances serves to illustrate the intermediate character of these solutions. The book, which is intended as a monograph, should not only be used as a work of reference by research workers in this field, but should also be of service to the general reader. For the purpose of the latter, however, since the chapters are so full of material, a summary at the end of each chapter would considerably improve its usefulness. It is one of the best of the monographs of the American Chemical Society Series.

W. E. G.

**Distillation Principles and Processes.** By SYDNEY YOUNG, D.Sc., F.R.S., with the collaboration of E. BRIGGS, D.S.O., B.Sc., T. HOWARD BUTLER, Ph.D., M.Sc., F.I.C., THOS. H. DURRANS, M.Sc., F.I.C., F. R. HENLEY, M.A., F.I.C., JAMES KEWLEY, M.A., F.I.C., and JOSEPH REILLY, D.Sc., F.R.C.Sc.I., F.I.C. [Pp. xiii + 509, with 210 illustrations.] (London: Macmillan & Co., Ltd., 1922. Price 40*s.* net.)

THE usefulness of a scientific book can often be gauged by the difficulty in obtaining a second-hand copy when it is out of print. Those who purchased Prof. Young's *Fractional Distillation* evidently found it too valuable to part with as, for some time before the appearance of the new work, second-hand copies of the earlier volume were exceptionally rare. *Distillation Principles and Processes* is, therefore, very welcome, embodying as it does the material of *Fractional Distillation*, brought up to date with considerable revision and amplification, together with accounts of the application of distillation processes in connection with the manufacture of acetone, alcohol, petroleum products, coal-tar products, glycerine, and essential oils.

The first part of the book, which deals with the general principles of distillation and follows the arrangement of Prof. Young's earlier book, calls for little detailed criticism. More attention, however, might have been paid to practical application in the laboratory, for example, although the dehydration of alcohol by making use of the minimum-boiling ternary mixture benzene-alcohol-water is described, no mention is made of the application of this principle to the removal of water during esterification.

The technical application of distillation processes is new matter, and each branch has been dealt with by one or more writers who have special experience in the particular field under consideration. A fairly uniform method of treatment has been maintained throughout this section; a short introduction dealing with the sources of raw material is followed by a description of the distillation methods commonly in use with diagrams of the various types of plant, tables of relevant data, and some account of special difficulties and problems which have to be considered. Chapter XL, on Steam Distillation, in the section on Essential Oils, rectifies an important omission in the general part of the book where this subject is very much neglected. The wisdom of adding descriptions of plant is perhaps open to doubt. This occupies more than half of the book, and it is doubtful if the honours student of chemistry gains much from such information; a few days in the works would be of more value than much reading, especially as exigencies of space, etc., often lead to modifications in plant design, and change is so rapid that any textbook is soon out of date. One feels the particular force of this objection in the very large increase in cost of the book over the original *Fractional Distillation*. The theoretical part should be read by every student of chemistry, but the price of the new edition has placed it beyond the reach of many who have not ready access to a good chemical library. On the other hand, as with most technical textbooks, insufficient details of plant are given to make this part of any great value to the specialist in technical distillation.

O. L. B.

**The Volatile Oils.** Vol. III. By E. GILDEMEISTER and FR. HOFFMANN. Second Edition by E. GILDEMEISTER. Authorised translation by EDWARD KREMERS. [Pp. xx + 777, with 5 maps, 1 table, and numerous illustrations.] (London: Longmans, Green & Co., 1922. Price 32*s*. net.)

THIS volume completes the English translation of the second edition of Gildemeister and Hoffmann's well-known book, compiled under the auspices of Schimmel & Co., and concludes the description of the individual essential oils begun in the second volume. The work, now grown to three large volumes, is a wonderful repository of information on the origin, production, properties, and composition of the essential oils, not only those of commercial importance, but of practically all those which have been extracted even if only on an experimental scale. It is difficult, therefore, to imagine how anyone interested in this branch of chemistry can deny himself the convenience of having these volumes on his shelves. The large number of references to work carried out in Schimmel & Co.'s laboratories indicate the thoroughness of the research organisation of this firm, and the making of their information available in so convenient a form is a custom which might well be followed elsewhere to the advantage of the progress of chemistry. Although each volume is indexed separately, Vol. III contains a general index to the whole work extending to 100 pages; this greatly facilitates reference. The general get-up of the book might be described as sumptuous, but unfortunately the English, though not actually incorrect, is far from idiomatic. Though this does not detract from the value of the book in the scientific sense, it is a pity that so painstaking a work should be marred by a fault so easily remedied.

O. L. B.

**Priestley in America, 1794–1804.** By EDGAR F. SMITH. [Pp. 173.] (Philadelphia: P. Blakiston's Son & Co.)

THE author opens his text with the words: "There lies before the writer a tube of glass eleven and one-half inches in length and a quarter of an inch in diameter. . . . Attached to the tube is a bit of paper upon which appear the words 'piece of tubing used by Priestley.' That legend has made the tube precious in the heart and to the eye of the writer." One wishes that there were still a Calverley to enshrine this gem with the historic cherry stones.

There follows an attempt to give some account of Priestley's life in the United States in which his scientific work occupies but a minor part. The major part of the book deals with addresses of welcome, defences from theological and political opponents and gossip which, while they add little to our knowledge of Priestley, show that the controversialist's path in the United States was little smoother than in England.

The author has the unfortunate disability of being unable to refer to any public character without one or more qualifying adjectives, a habit which, coupled with a general lack of style, is very irritating to those acquainted with the classical essay of Sir Edward Thorpe whom the author characteristically refers to as the noble-hearted, sympathetic Thomas E. Thorpe. The author is ill-advised if he thinks that such a production will add one iota to the reputation of Joseph Priestley.

O. L. B.

**The Chemistry and Technology of Gelatin and Glue.** By ROBERT HERMAN BOGUE, M.Sc., Ph.D. (Mellon Institute Technological Series.) [Pp. xi + 6[illegible], with 118 figures.] (New York and London: McGraw-Hill Book Co., 1922. Price 30s.)

HITHERTO anyone who has had occasion to deal with gelatin and glue has known that there was an immense amount of information scattered through the various scientific and technical journals of all countries, but at the same time he has been confronted with the fact that there was no adequate summary of the existing knowledge. Moreover, the existing data were so varied in character and very often so contradictory that the task of making a summary which was something other than a mass of apparently disconnected facts seemed almost hopeless. Dr. Bogue, however, who is well known for his investigations on gelatin and glue, has not been dismayed by the task before him and has been eminently successful in correlating and summarising the material at his disposal and in giving a clear and readable account of the subject. After an introduction dealing with historical and statistical considerations, the theoretical aspects of the subject are considered. These include: the constitution of the proteins; the chemistry of gelatin and its congeners; the physico-chemical properties and structure of gelatin; gelatin as a lyophile and as an amphoteric colloid. In this part of the book ample justice is done to the pioneering work of Procter, Pauli, Loeb, and Brailsford Robertson; if anything, the author is somewhat too lenient towards the views of Robertson, whose peculiar ideas on the dissociation of proteins appeal to only a few.

The second part of the book deals with the technological aspects of the manufacture, testing, chemical analysis, uses and applications of gelatin and glue. The point of view taken is that of the chemist rather than that of the plant technologist, and this makes the appeal of the book all the greater to the student and investigator. The technologist, however, does have the scientific principles underlying the various processes brought very clearly before him and cannot fail to profit from a close study of the book. There is a special chapter on water-resistant glues and glues of marine origin, which should be read in conjunction with the first report of the Adhesives Research Committee. An appendix deals more especially with the electrometric and indicator methods of determining hydrion concentrations.

The book is well printed and very few misprints have been noticed. One sentence on p. 141 requires revision, and the choice of acetic acid to illustrate the properties of an amphoteric substance (p. 221) seems very unfortunate. The literature references given are very full, but not quite complete; they are amply sufficient, however, for the object the author had in view, namely, to give a connected and clear account of the chemistry and technology of gelatin and glue. T. S. P.

**Researches on Cellulose, IV** (1910–1921). By CHARLES F. CROSS and CHARLES DORÉE. [Pp. x + 253, with four plates and 12 diagrams in the text.] (London: Longmans, Green & Co., 1922. Price 15s. net.)

THIS volume is the fourth of the well-known series "Cross and Bevan," the place of the late Mr. Bevan being taken by Mr. Dorée. The long interval which has elapsed since the appearance of Part III makes this volume the more welcome, especially as there has been increased activity connected with the scientific and technical problems related to cellulose both during and since the war. The book is divided into seven chapters dealing amongst other subjects with the Physical Properties and Constitution of Cellulose, while the last three are entitled "Oxycellulose and Hydrocellulose," "Lignocelluloses and Lignone," "Cellulose Industries and Technology" respectively. The general arrangement is substantially the same as that followed in the earlier volumes, each chapter containing abstracts of a selection of the more important researches dealing with the subject concerned, followed by a short critical summary. This method of treatment is particularly valuable where the author's views are at variance with those of the writer of the paper, for Mr. Cross's experience is of course unrivalled and his opinion is always valuable. Throughout the book he presses his views concerning the mental attitude to be adopted towards cellulose, namely, that it is "a colloidal substance 'organic' in function and assuming, correlatively, highly specialised and infinitely varied structural forms . . . retaining, after separation from the plant, characteristics of reactivity impressed by the conditions of vital origin: a substance to be investigated *as it is*, therefore rather by physical methods including the methods of the physiologist and histologist." As an outcome of the continued reiteration of this attitude Mr. Cross is inclined to treat rather unsympathetically those purely chemical workers who attempt in the first instance merely to elucidate the composition of the $(C_6H_{10}O_5)n$ complex, as distinct from the naturally occurring colloidal aggregate of the fibre. Regarding the somewhat elusive terms hydrocellulose and oxycellulose the authors state that "there are no lines of demarcation or differentiation justifying these terms as applied to chemical individuals and that they rather connote reactions and the products represent phases of equilibrium . . . ." a statement which can hardly be said to make the position much clearer. With regard to the constitution of Lignocelluloses there is no tendency shown to recede from the view originally put forward by Cross and Bevan or to accept any of the views of other workers, although the present authors reveal a sympathetic feeling towards the physical view of the union between the carbohydrate and the lignone, a view which receives support from the rather remarkable observations of Robinson which are interpreted by this author as "a displacement of adsorbed lignone originally in the form of films overlaying the ground cellulose of the tracheides." A perusal of this very interesting and suggestive volume leaves one with a feeling of the immense complexity of the subject and the distance which has yet to be covered before the complete story can be told.

**Creative Chemistry.** By EDWIN E. SLOSSON, M.S., Ph.D. [Pp. xii + 311, with 38 illustrations.] (London: University of London Press, 1921. Price 12*s.* 6*d.* net.)

THIS book is one of the series of New Century Books of Useful Science, and originated in a series of articles written in 1917–18 for an American journal for the purpose of interesting the general reader in the recent achievements of industrial chemistry. It may be said at once that it would indeed be a dull reader who would fail to be interested, and it would be difficult to imagine a book better adapted to the purpose for which it was written. Each chapter is complete in itself, dealing with one or other aspect of applied chemistry, and in every case the significance to the community of properly trained chemists is manifest, the author throughout making a strong appeal for the maintenance of an efficient chemical service within his own country. In an entirely unconventional and highly entertaining manner the author places before his readers a wealth of information in such a way as to make everything appear easily intelligible even to the entirely uninitiated, but a perusal of the book may also be recommended strongly to advanced students. A glance at the table of contents might surprise or even prejudice the serious reader, as the titles of the chapters flavour rather of cheap American journalism than of serious reading: as, for example, Feeding the Soil, The Race for Rubber, The Rival Sugars, Solidified Sunshine, etc.; but on closer acquaintance with the contents of any one of these chapters the said reader will soon see that first impressions are not always to be relied upon. It is not contended that all the articles are equally good, but it is easy to see that the writer, besides being endowed with that priceless gift a sense of humour, is also a widely read man and a philosopher, and the result is a highly instructive as well as entertaining book. Started as it was during the war, and completed in book form after the declaration of peace, the book naturally presents the subject from the point of view of the war, and points the lesson and further reveals much of the information which was not available to the general public during the war; this applies especially to the chapter on Gas Warfare, entitled, "Fighting the Fumes." Enough has been said to recommend the book to as wide a circle of readers as possible, whether possessed of chemical knowledge or not.

P. H.

**All About Coffee.** By WILLIAM H. UKERS, M.A. [Pp. xxxii + 796.] (New York: The Tea and Coffee Trade Journal Company, 1922. Price 70*s.* net.)

THE author, who is editor of the *Tea and Coffee Trade Journal*, of New York, has evidently undertaken this compilation as a labour of love, since the actual writing of the manuscript has, according to his own words, extended over four years, while the sorting and classification of material was commenced ten years ago. It must certainly be acknowledged that the title of the book very aptly describes its contents, for the author has produced what to all intents and purposes may be described as an encyclopædia upon coffee. By consulting the principal European libraries and museums, the material has been obtained for the first fourteen chapters, which are of antiquarian interest—being concerned chiefly with the history of the introduction of coffee into each of the more important European countries, and into America, as well as giving particulars of the coffee-houses in which it was consumed. Then follow four chapters dealing with the more scientific aspects of the question, namely the Botany of the Coffee Plant, the Microscopy of the Coffee Fruit, the Chemistry of the Coffee Bean, and the Pharmacology of the Coffee Drink, the two latter from the pen of Mr. Charles W. Trigg, of the Mellon Institute of Industrial Research in Pittsburgh. The chemistry of the constituents of the plant and of the effect upon these of roasting is skilfully summarised and is quite up-to-date ; the chapter is brought to a close with the details of the methods of chemical analysis of coffee as recommended by the Association of Official Agricultural Chemists. In the section on Pharmacology the physiological action of the more important constituents is discussed, and emphasis is laid upon the fact that the coffee plant contains no true tannin of the type which precipitates proteins and is a fruitful source of indigestion. The botanical chapters describe in plain language the morphology of the various species of cultivated and wild plants, as well as hybrids and the caffein-free trees of Madagascar. The remaining chapters deal with the cultivation of the plant, the preparation of green coffee, details of marketing both wholesale and retail, the history of coffee advertising, coffee in relation to literature and the fine arts, the evolution of coffee apparatus and the world's coffee manners, only to mention a few of the numerous subjects discussed. At the end come a coffee chronology and coffee bibliography of 12 and 30 pages respectively. Profusely illustrated throughout, and with a number of coloured plates, the book provides a mass of information for those connected with the trade, for experts, and for the mere layman who, as an inquisitive devotee, wishes to know more about his favourite beverage.

P. H.

**A Laboratory Handbook of Biochemistry.** By P. C. RAIMENT, B.A., M.R.C.S., L.R.C.P., and G. L. PESKETT, B.A. [Pp. 100.] (London : Edward Arnold & Co., 1922. Price 5*s*. net.)

WE had looked for a better conceit in the biochemist of to-day. The time has surely passed when the clinical examination of urine and blood, of foods and digestive juices, might legitimately claim the name of Biochemistry, and the authors had been better advised to have been content with a less exacting title. The book has evidently been produced to meet the demands of an overburdened medical curriculum, but even with such unpromising material we feel that a more helpful book might have been compiled—if compiled it must be. Into one hundred pages has been condensed just enough chemistry to enable the unfortunate student to slip through the fingers of the equally unfortunate examiner. The examination method of treating physiological chemistry is here epitomised and stands condemned, whilst the necessity for embellishing the practical notes with some theoretical considerations has led inevitably to many loose and misleading statements. We read that " everything that has been said about the globulins applies to the albumins," that the proteins " present two distinct kinds of properties : (i) chemical, and (ii) physical," and that the alkalinity of the pancreatic juice is " roughly equal to the acidity of the gastric juice." Again, we are counselled, in hints on the identification of unknown substances, that a smell of almonds on heating to dryness indicates uric acid, and that a precipitate produced by ammonium chloride may be uric acid or soap—if the murexide test is positive it is the former, if negative it is soap.

This is certainly not good chemistry ; we are doubtful if it is good cramming.

R. K. C.

## BOTANY AND AGRICULTURE

**Recent Progress in Rubber Chemistry and Technology.** By PHILIP SCHIDROWITZ, PH.D., F.E.S. [Pp. 64.] (London : Benn Bros., 1922. Price 3*s*. 6*d*. net.)

THIS little book must be judged as a survey of recent developments in the various branches of the rubber industry, addressed to those who are already familiar with its general principles, and in the limited space of some fifty pages the author has succeeded in presenting clearly and attractively the more important scientific and technical developments which have taken place during recent years, and the many problems which still await solution.

The first chapter deals with the production of rubber and shows the striking increase in the demand for rubber, due to the development of motor transport. The various questions, such as the yield of latex, methods of tapping, coagulation, and quality of the product, are discussed, and reference is made to the commercial possibilities of the drying oil expressed from the hevea seeds.

The subsequent portions of the book are devoted to the properties of rubber itself and some of the outstanding problems arising in the course of its conversion into useful articles. Amongst other matters, the latest investigations on such questions as the constitution of rubber, stress-strain curves, correct "cure," synthetic rubber, vulcanisation and vulcanisation accelerators, the effect of the particle size of compounding ingredients on the physical properties of the rubber, and accelerated ageing tests receive brief and critical notice.

Those engaged in specialised work, from the nature of things, must be liable to become parochial in their views, and for this reason clearly written surveys covering a wide field meet a need which is not filled by the larger work of reference. From this point of view the present little book may be heartily recommended to all interested in the scientific problems connected with rubber and the development of an important modern industry.

B. O. Porritt.

**Researches on Fungi. Vol. II, Further Investigations upon the Production and Liberation of Spores in Hymenomycetes.** By A. H. Reginald Buller, B.Sc., D.Sc., Ph.D., F.R.S.C. [Pp. xii + 492, with 157 figures in the text.] (London: Longmans, Green & Co., 1922. Price 25*s.* net.)

The first volume of Prof. Buller's *Researches on Fungi* appeared in 1909. In this work new fields of research were opened and new methods were applied to what proved an extremely interesting and stimulating subject. In the thirteen years that have elapsed since the publication of that very valuable piece of biological work, Prof. Buller has been engaged in further observations and ingenious experimentation, and has accumulated results sufficient to fill three new volumes, of which this is the first. The earlier volume dealt with the biology and physics of spore dispersal in the Hymenomycetes, with observations on spore discharge and dispersal in the Ascomycetes and Pilobolus.

In this new volume Prof. Buller deals in an even more detailed manner with the economy of the fruit-bodies of *Panæolus campanulatus*, *Stropharia semiglobata*, and *Psalliota campestris*, all fungi which belong to one of the subtypes into which he has divided the non-deliquescing Hymenomycetous fruit-bodies. In all these forms the gills exhibit mottling due to the spores in different areas on the gills ripening at different times. The author has observed, using a new direct method, the development of basidiospores on particular areas of the hymenium, and by this and other means has been able to construct figures which he claims are the first to give a correct idea of its structure. He has given further proof that no basidium is able to form more than one set of spores and that these spores are discharged successively. As to the exact method of spore discharge, he seems less sure than in his earlier work, and is of the opinion that much more research is required into the nature of the attachment of the spore to the sterigma before any conclusions can be arrived at. He draws attention to the existence of a hilum in spores that are shot away violently (it is absent in Gasteromycetes), and to the excretion of a drop of water at the hilum immediately before spore discharge. The drop of water increases the weight of the projected spore, and so causes the projectile to be carried a greater distance away from the hymenium than if the spore were dry; it is attached at the forward end of the spore and causes the latter to adhere to any surface that it may come in contact with. In Vol. I of the *Researches* it was shown that there was a considerable discrepancy between the time of fall as calculated from Stokes' law and the observed figures; it is here pointed out that the increased weight of the spore due to its carrying with it the drop of water mentioned above would partly, if not completely, explain the difference between the observed and the calculated figures.

Other chapters are concerned with the Red Squirrel and Slugs as mycophagists, with the spore discharge in Hydneæ, Clavariæ, Polyporeæ, and the questions of the efficiency of such fruit-bodies for spore discharge. The author is to be congratulated on a very notable work and an extremely fascinating one. He has certainly proved his contention that "the form and arrangement of parts exhibited in the sporophore of the Common Mushroom and its allies appear to be no less beautifully fitted for the efficient production and liberation of spores than are the form and arrangement of Orchid flowers for securing successful pollination by insects."

**The Fundamentals of Fruit Production.** By VICTOR RAY GARDNER, FREDERICK CHARLES BRADFORD, and HENRY DAGGETT HOOKER, junr., of the Department of Horticulture of the University of Missouri [Pp. xvi + 686.] (New York and London: McGraw-Hill Book Company, 1922. Price 22*s*. 6*d*.)

ALTHOUGH books abound dealing with the practice of horticulture in general or of particular branches of it, the literature of the scientific principles underlying horticultural practice remains for the most part in the form of records of original research scattered through scientific journals or published as reports from agricultural and horticultural research stations. For this reason, if for no other, the work under review would find a welcome. The authors have, however, covered the field so thoroughly, and presented the principles of fruit-growing and the facts on which the principles rest so well, that this work must for long remain a classic not only of horticultural, but also of scientific botanical, literature.

The book is divided into seven sections dealing respectively with water relations, nutrition, temperature relations of plants, pruning, fruit-setting, propagation, and geographic influences in fruit production. As the authors rightly state, "The plant's growth and functioning depend on the nature of the environment and the adjustment thereto and not directly on cultural practices, which only modify the relation of the plant to the environmental complex." Thus horticultural practices are not prominent in the headings of the sections and chapters. This is as it should be in a book dealing with the scientific principles of a plant study; nevertheless, as cultural practice may alter the conditions of the environment, these cannot be neglected even in a book dealing thoroughly with principles, and we find adequate references to cultural practices throughout the work.

The book can be thoroughly recommended not only to serious scientific students of horticulture, but also to botanists who wish to possess a summary of the present position of our knowledge of an aspect of the growth of the plant too often neglected. The adequate lists of literature at the end of each section will be found useful to the student who wishes for further information on the subjects dealt with.

W. S.

**Agricultural Bacteriology.** By JOSEPH E. GREAVES, M.S., Ph.D., Professor of Agricultural Bacteriology and Physiological Chemistry in Utah Agricultural College. [Pp. xv + 437.] (Philadelphia and New York: Lea and Febiger, 1922.)

THIS work deals not only with agricultural bacteriology in the narrow sense, but includes accounts of such related topics as bacteria in air, water bacteriology, water and disease, sewage and sewage disposal, bacteria and food-poisoning, preservation of food and bacteria in the arts and industries. The various parts of the subject are dealt with in different degrees of detail, such questions as the bacteriology of milk, water, and sewage being considered simply in outline because books dealing adequately with these questions are already available. The parts of the subject particularly well treated by the author are the general morphology, classification, and physiology of bacteria which form the subject-matter of the first twelve chapters of the book, and bacteria in relation to the soil, a subject which is dealt with in all its aspects and in considerable detail, chiefly in the next fourteen chapters. The rest of the book deals with a number of miscellaneous questions related to agricultural bacteriology, including those noted above.

The book is well written and well produced and forms a notable addition to the literature of bacteriology in relation to agriculture and allied subjects.

W. S.

**Guide to the University Botanic Garden, Cambridge.** By HUMPHREY GILBERT-CARTER. [Pp. xvi + 117, with frontispiece, 23 plates, and a plan of the garden.] (Cambridge: at the University Press, 1922. Price 3*s*. 6*d*. net.)

THIS excellently printed and original volume belies the usual conception of a guidebook. It is rather a pot-pourri of interesting information respecting a number of selected types arranged on a taxonomic plan.

No matter where we casually open its pages, the reader will find information of interest, whether it be the discontinuous distribution of *Arbutus*, the insectivorous habits of the Pitcher plant, or the drugs obtained from the Elecampane by the pharmacists of the past, and the source of liquorice at the present day. The freshness of treatment in this guide by the Director of the Gardens augurs well for their future development.

The book is well illustrated, there is an excellent index, and the price is very moderate. It should find a circle of readers even wider than those who visit the gardens themselves.

E. J. S.

## ZOOLOGY

**Foundations of Biology.** By LORANDE LOSS WOODRUFF, Professor of Biology in Yale University. [Pp. viii + 476, with 211 illustrations.] (New York: Macmillan Company, 1922.)

WITHIN a short space of time we have noted in England the publication of several new books on Junior Zoology—*e.g.*, those of Meek, Graham Kerr, O'Donoghue, and a new edition of Parker by Bhatia. The fever seems to have started in America, and this book by Woodruff contains, as did mainly those above-mentioned English examples, the results of the author's lectures to junior students of Medicine, Forestry, and General Science.

All these textbooks are much alike, but the American ones do bring in more of the modern work in cell physiology and heredity. Unless, however, Woodruff's book is read in conjunction with some good practical classes it would be unsuitable for classes of medical students. The book seems to us to be more suitable from the purely educational rather than from the point of view of training as a basis for the anatomy, physiology, embryology, and parasitology of later medical studies. Its interest and charm is undoubted, and if taken in conjunction with good practical classes in Biology, we believe it will serve its purpose admirably. The illustrations are clear and well chosen.

J. BRONTÉ GATENBY.

**Essentials of Zoology.** By ALEXANDER MEEK, Professor of Zoology, University of Durham. [Pp. vi + 325, with 145 illustrations.] (London: Longmans, Green & Co., 1922. Price 10s. 6d.)

LIKE Woodruff's book, and the less recent ones of Graham Kerr and O'Donoghue, Meek's *Essentials* is an introductory course for students of Medicine, Agriculture, or General Science. The figures throughout do not appear to us to have been very well drawn or reproduced; all the usual types are taken and treated thoroughly, and the book is in every way suitable as an introduction to Morphology and Embryology, for the medical and general biological student. Since, however, there is no treatment in the history of the science, of Heredity, Sex, and Evolution, the book cannot be considered quite complete. We think that the treatment of some of the chapters is novel and attractive; something of the modern physiological outlook has been introduced here and there. A new edition should contain the sections mentioned above; at present it does not fulfil the recommendations of the General Medical Council. Some of the scratchy illustrations should be done again.

J. BRONTÉ GATENBY.

**Catalogue of Cretaceous Bryozoa.** Vol. IV. By W. D. LANG, Sc.D., F.G.S. [Pp. xii + 404.] (British Museum (Natural History), 1922. Price 32s. 6d.)

THIS systematic treatise by Dr. Lang is the fourth of a series on the Cretaceous Bryozoa, and is a direct continuation of vol. iii, completing the catalogue of the Cretaceous Cribrimorph Cheilostomata.

The first two volumes were compiled by Dr. Gregory, and included the Cyclostomatous and Trepostomatous Bryozoa. This volume deals solely with the large family Pelmatoporidæ—Turonian to Danian, Cribrimorphs in which two rows of pelmata or pelmatidia form markings on the intraterminal front wall. Though the work is essentially systematic in character, it is superior to many catalogues in combining fact and theory, and is not merely a collection of observed facts. As in the third volume the classification is based on palæontological principles which have only recently become evident, and the evolution of each character from its primitive condition is fully discussed.

A. E. CLARK.

**Handbuch der biologischen Arbeitsmethoden.** Abt. ix, Methoden zur Erforschung der Leistung der tierschen Organismus, Teil 1, Heft 2. By HANS PRZIBRAM and others. [Pp. 98–438.] (Berlin: Urban & Schwarzenberg, 1922. Price 2,160 mks.)

THIS is the ninth part of a series of technical works dealing with Zoology, Physiology, Pathology, etc. The present volume deals with the handling, dissection, drawing, macro- and micro-injection, clearing and preservation of animals. Reconstruction methods, and the putting up of museum specimens, are dealt with. Microscopical technique is not specially reviewed.

There are some peculiar sections, *e.g.*, "Method for the Finding of the Food Plants of Insects," "Methods for the Making of Text-figures by the

Author." There is a chapter on "Durchsichtigmachen," which is now so popular among anatomists and embryologists. The volume will be useful for the following persons—zoologists interested in museum preparations, anatomists, and embryologists who work especially on vertebrate material, and for laboratory technicians who can read German.

J. BRONTÉ GATENBY.

**The Wonderland of the Eastern Congo.** By T. ALEXANDER BARNS, F.R.G.S., F.Z.S. [Pp. xxxv + 288, with a map and 108 Illustrations from photographs by the author.] (London: and New York G. P. Putnam's Sons. Price 31*s.* 6*d.* net.)

*The Wonderland of the Eastern Congo* is a delightful book. The author is not only a mighty hunter but a sound field-naturalist and a keen explorer, who tells his tale with a sincerity and modesty which in these days of self-advertisement is quite charming. The book has something for everyone interested in Africa, be they administrators, travellers, prospectors, sportsmen, or naturalists. To our greatest living African administrator and scholar, Sir Harry Johnston, who has honoured this book with a learned introduction, chapter xiv must bring back many happy memories of the past and tell what giant strides these regions of the Eastern Congo have made during the last two decades since he himself first helped to open them up.

The author gives the Belgians every credit for the part they are playing in the opening up and development of the natural resources of their vast dependency, which surely must in the near future become the richest colony in the African Continent. Mr. Barns gives us a very good account of the mineral resources of the regions he passed through. Katanga, with its untold wealth of copper, tin, gold, cobalt, uranium, and platinum, is daily drawing Europeans in ever-increasing numbers to the very heart of Africa.

To the general reader the chapters on the Virunga Volcanoes and the Gorilla-hunting will probably appeal the most, but the whole of this delightful book is interesting.

Mr. Barns's picturesque style is at its best when he takes us into the haunts of the okapi and introduces us to the pygmies in the Semliki forest. The author was fortunate in obtaining such a fine specimen of the Kivu Gorilla, but, expert hunter though he is, the elusive okapi, that rarest and quaintest of African mammals, was to evade him as it has evaded all other European sportsmen.

That the dense forests of Congoland still hold a fauna only the fringe of which has been touched there can be little doubt, and reports true and untrue will continue to be brought to travellers and sportsmen of wonderful beasts to be found in the forest, rivers, and swamps of this wonderful country.

The chapter on elephants will interest all sportsmen. The author is probably correct in his suggestion that the blackness of the ivory of the forest elephant is due to the juices of some favourite food of theirs. This juice mixing with the saliva probably acts on the growing ivory, rendering it black. The black colour of the dung of these elephants confirms this view.

Those who have hunted the wild beasts and followed the native tracks of unknown tropical Africa and who in all human probability will never go on "safari" again, this book will fill with delight. Would that more of the books on sport and travel that yearly attempt to describe Africa could come up to the standard of this charming and handsome volume. We congratulate the author and his courageous wife who shared with him the delights and dangers of a wonderful journey.

R. E. DRAKE-BROCKMAN.

**The Coccidæ of Ceylon.** By E. E. GREEN, F.E.S. **Part V.** [Pp. 345–472. Plates cxxxiii–cxci*a*.] (London: Dulau & Co., 1922. Price £3.)

THE appearance of the final part of this important work completes a laborious task upon which Mr. Green has been engaged for a lengthy period. Its publication has extended over twenty-six years, the first part having appeared in 1896, and the author must have devoted a long time to preliminary study before embarking upon the venture at all.

The fauna of Ceylon is a very rich one, and nearly 300 species of Coccidæ are now known from that region. Mr. Green's work, however, is much more than of mere faunistic value. It serves as a general introduction to the family of insects with which it deals and a work of reference to the specialist. Whatever taxonomic changes are introduced in the future, we believe that this monograph will hold its own for many years upon the general excellence of its very detailed plates apart from any other feature. The morphologist will turn to it for its wealth of structural detail, and the biologist will find a great mass of information on the metamorphoses of the various species concerned. Mr. Green's monograph is generally recognised as the most important treatise on its group that has yet appeared, and he is to be heartily congratulated upon its completion. The successful production of the final volume during the arduous years of the war, with the maintenance of the same high level as its predecessors, is a triumph in itself. A. D. IMMS.

## MISCELLANEOUS

**The American Indian.** By CLARK WISSLER. [Pp. xxi + 474, with 2 maps and 83 illustrations.] (New York and London: Oxford University Press, 1922. Second Edition. Price 24*s*. net.)

IT is a common failing in much of the literature of social anthropology that the writers lose their thesis in the mass of details which they describe. No such accusation can be brought against this extraordinarily entertaining book on the American Indian. In the first chapter we are shown the food areas of the New World, as being the fundamental conditioning factors of human life in the two continents; and then the author passes in review various phases of aboriginal culture, such as domestic animals, ceramic arts, architecture, social regulations, and the literature of the Mayas and Aztecs; then he proceeds to deal with archæology, chronology, and somatic classification; and finally at the end of the book we are brought to great generalisations on the origin of the American native. Thus the book has a unity of conception which is quite admirable. Mr. Wissler holds strongly to the view that the American civilisations were evolved quite independently of the Eastern Hemisphere, and in favour of this opinion he cites, among other points, the absence of any idea of the wheel in the Western Hemisphere, and the fact that at the time of the discovery of America, all the cultivated plants were peculiar to the Western continents. The absence of the wheel is certainly a negative point of much importance, having regard to the practical value and antiquity of the discovery of the wheel in Eurasia. The origin of the Red Man is considered at length. The ancestors of the American Indian were no doubt Mongoloid savages who made their way across the Behring Strait—or Behring Isthmus, as it may then have been—in comparatively recent times. As to the date of the first colonisation, there is difference of opinion. Hrdlicka thinks it was a post-glacial migration. But Mr. Wissler thinks this gives insufficient time for American developments, and he thinks the Red Man must have arrived before the last glacial period—that is, not later than the last interglacial period. Certainly, the amazing linguistic diversity of the natives makes one sceptical of anything so recent as a post-glacial colonisation. A. G. T.

**L'Industrie du Fer en France.** Par J. LEVAINVILLE, D. ès L. [Pp. vi + 211, with 4 maps.] (Paris: Collection Armand Colin. Price 5 frs. net.)

THE experience acquired by the author of the iron mines and deposits of France and North Africa enables him to write with authority on the economic aspect of the French iron industry. In this book the subject has been treated from the historical, technical, and economic points of view and the work is of value as a guide to the activities in France both before and since the war. A brief account is given of the chief ore deposits of France and Africa, and the historical survey of the industry as presented by the author proves interesting reading. Until the middle of the nineteenth century France made little progress, but from that time onwards the growth of the industry has been rapid, and the author considers that when the works have been reconditioned after the war, France should occupy second place—immediately following the United States—in this industry. The increased consumption, for home requirements and for export, is clearly indicated; the former due to the growing demands for mechanical transport of all kinds and to the increasing use of iron and steel in structural and mechanical work. A valuable addition, which we should like to see more often in technical books, is the extensive bibliography at the end of each chapter.

E. COURTMAN.

**L'Acier** (Elaboration et Travail). Par COLONEL JEAN ROUELLE. [Pp. vi + 200, with 45 illustrations.) (Paris: Collection Armand Colin. Price 5 frs. net.)

IN this little work the author has provided a concise introduction to the metallurgy of steel which will enable the reader to gain a good knowledge as to the importance of the modern steel industry. This has been achieved in spite of the limited space available in which to describe the many processes now in use for the production and subsequent working of steel, and considerable credit is due to the author for his careful selection of the information. The first section traces the manufacture of steel from cast iron to the finished product, and includes all the usual processes now employed. Compared with the other processes, crucible steel does not appear to have received sufficient attention, for although, as the author mentions, the amount produced is very small, the product is of considerable importance and of high commercial value.

It is satisfactory to notice that in a work of this nature a chapter is devoted to the special steels, which are attaining an important position with the increasing use of the electric furnace and the growing demand for high tensile and non-corroding materials.

The second section deals briefly with the constitution and testing of steel and describes the various processes of mechanical treatment. The importance of heat treatment, without which the valuable properties of the special steels cannot be utilised, is not overlooked, a chapter being given to its consideration.

The illustrations are chiefly diagrammatic; especially is this the case with those of furnaces, which indicate the main features but are in no sense drawings of modern furnaces.

The author is to be congratulated on adding a very useful volume to the Armand Colin Collection and to steel metallurgy in general.

E. COURTMAN.

**Les Applications Élémentaires des Fonctions Hyperboliques** à la Science de l'Ingénieur Électricien. Par A. E. KENNELLY, D.Sc. [Pp. vii + 151, with 31 illustrations.] (Paris: Gauthier Villars et Cie., 1922. Price 15 frs.)

THIS book gives a concise and simple introduction to the applications of the theory of hyperbolic logarithms to electrical problems.

The author himself has played a leading part in the development of the practical side of the theory which is now in everyday use both by Post Office engineers in connection with telephony and by consulting engineers when designing power transmission lines. The same theory can be applied in both cases, but it is perhaps more accurate for the case of overhead telephone transmission. The author introduces some novel units as, for example, the abhenry and the statfarad. He also writes logh $x$ for $\log_e x$, *i.e.* for the naperian logarithm of $x$. As a rule, however, he uses international symbols and nomenclature. The book presupposes very little mathematical knowledge on the part of the reader, and as it is very clearly written it can be recommended to every engineer who desires to acquire the ability to solve transmission problems at first hand. It can be specially recommended to every young electrician. A. RUSSELL.

**Greek Biology and Greek Medicine.** By CHARLES SINGER. [Pp. 128, with 21 illustrations.] (Oxford: at the Clarendon Press, 1922. Price 2*s*. 6*d*. net.)

IN less than 130 pages Dr. Singer has given us, in the book under review, a very interesting sketch of the history of Greek Biology and Greek Medicine and their influence on subsequent ages. He has even found room for quite a number of picturesque and helpful illustrations. This is Dr. Singer's third attempt to present his theme to a wide circle of readers. Last year we had from his pen a full account of "Greek Biology and the Rise of Modern Biology" in the second volume of *Studies in the History and Method of Science* edited by him, and already reviewed in these pages. Early in the present year he contributed to *The Legacy of Greece* (a volume edited by Mr. R. W. Livingstone) two papers devoted respectively to "Greek Biology" and "Greek Medicine." And now we have this welcome summary. Quite apart from the difficulty of presenting the same material in several forms, the subject bristles with difficulties. The scantiness of the records, the corruption of the texts, the uncertainty of their correct interpretation and the difficulty of determining their date and origin are sufficient to tax anyone's ingenuity. All considered, Dr. Singer is to be congratulated on the measure of success which he has achieved. But he will be the first to admit that he is open to criticism in various ways. Some of his statements about Aristotle, Pythagoras, and others are hardly intelligible, if not actnally misleading, for those unfamiliar with the fundamentals of their philosophies. Considerations of space had, no doubt, to be taken into account, but it would have been better to have omitted Greek quotations, footnotes, and less important passages in the text. Then, again, Dr. Singer is a great enthusiast for his subject, and enthusiasm has an unfortunate tendency to run away with one's judgment. For instance, after admitting that we really know nothing about the life of Hippocrates, our author promptly proceeds to speak of him almost in the glowing terms of a religious enthusiast! And his imagination finds all sorts of charms in the visage of Hippocrates, although it is admitted that the existing busts of the Father of Medicine are not authentic portraits, but artistic fancies! Certainly such passages add to the readableness of the account. The general reader may even be specially grateful for them. A. WOLF.

**Architectural Drawing.** By WOOSTER BARD FIELD, Architect. With an Introduction and article on Lettering by Thomas E. French. [Pp. xii + 242, with 9 figures.] (New York and London: McGraw-Hill Book Co. 1922. Price 20*s*. net.)

To the architect drawing is a means to an end, not the end in itself. Efficient draughtsmanship is nevertheless of the utmost importance in the realisation of fine architecture, while the student must rely upon it as a fundamental means of expression and the medium by which success can be best assured. Apart from a knowledge of the technique of drawing and the use of instruments, which can be readily imparted, facility in draughtsmanship depends upon the powers of the individual strengthened by right teaching and continued practice. Accuracy combined with artistic feeling is indispensable: every line in an architectural drawing serves a definite purpose and—apart from purely pictorial representations of structures in perspective—the functions of an architect's drawing are to express his design and to represent forms upon paper in such a manner that they can be correctly interpreted by those whose business it is to translate them into solid material. The expression of ideas by means of sketches and scale drawings has been the primary concern of architects from the time of the great masters of the Renaissance and modern conditions of building necessitate the continuance of a fine tradition then established.

This is a workmanlike book, beginning with the principles of graphic methods of representation—orthographic, isometric, and perspective—and proceeding to their application in a variety of uses. A vital consideration in a book on such a subject is that the illustrations should be numerous and representative, and that they should be reproduced from good drawings which may serve as models to students and others. In this respect the book leaves little to be desired, the line drawings being clear and straightforward, but it has not been found possible to deal with the whole range of archtectural drawing. Inasmuch as scale drawing necessarily embraces the larger question of design and construction, three sets of "working" drawings are given showing complete plans, sections, elevations and details which incidentally introduce recognised symbols for different building materials and fixtures. It is to be regretted that less complex designs for a house, a church, and an office building have not been presented: to them ten, eight, and seven plates respectively are devoted out of a total of eighty-four, and although much is to be learnt from them they can scarcely be regarded as elementary studies to which a beginner could turn with most profit.

The book naturally represents American practice and the English student will come across a few technical terms and methods of construction with which he may be unfamiliar: reference to the glossary will no doubt minimise these difficulties. The Italian orders of architecture after Vignola are shown by well-filled plates. These are in line, but an earlier section of the book treats of shadow projection in such a way as to facilitate the preparation of "rendered" drawings of the orders which are required of the student in every school in these days. Not the least valuable chapter is that dealing with lettering. Good examples are given which may be safely followed, and in this, as in many respects, the book may be relied upon for sound guidance.

Arthur Stratton.

# BOOKS RECEIVED

(*Publishers are requested to notify prices*)

Cours Complet de Mathématiques spéciales. Par J. Haag. Tome III. Mécanique. Paris: Gauthier-Villars et Cie., 55 Quai des Grands-Augustins, 1922. (Pp. 188.) Price 12 frs.

La Composition de Mathématiques dans l'Examen d'Admission à l'École Polytechnique de 1901 à 1921. Par F. Michel et M. Potron. Paris: Gauthier-Villars et Cie., 55 Quai des Grands-Augustins, 1922. (Pp. 452.)

Introduction à la Théorie de la Relativité, Calcul différentiel Absolu et Géométrie. Par H. Galbrun. Paris: Gauthier-Villars et Cie., 55 Quai des Grands-Augustins, 1922. (Pp. 459.) Price 60 frs.

A Treatise on the Theory of Bessel Functions. By G. N. Watson, Sc.D., F.R.S., Professor of Mathematics in the University of Birmingham. Cambridge: at the University Press, 1922. (Pp. viii + 804.) Price 70*s*.

Calculus and Probability for Actuarial Students. By Alfred Henry, F.I.A. Published by the authority and on behalf of the Institute of Actuaries by Charles and Edwin Layton, Farringdon Street, E.C.4. London, 1922. (Pp. iv + 152.)

Prolegomena to Analytical Geometry in Anisotropic Euclidean Space of Three Dimensions. By Eric Harold Neville, Professor of Mathematics in University College, Reading. Cambridge: at the University Press, 1922. (Pp. xxii + 367.) Price 30*s*. net.

A New Manual of Logarithms to Seven Places of Decimals. Edited by Dr. Bruhns, Director of the Observatory and Professor of Astronomy at Leipzig. Thirteenth Stereotype Edition. London: Chapman & Hall, 1922. (Pp. xxiii + 610.) Price 12*s*. 6*d*. net.

Mathematics and Physical Science in Classical Antiquity. Translated from the German of J. L. Heiberg by D. C. Macgregor. Chapters in the History of Science, No. 11. General Editor, Charles Singer. London: Oxford University Press, 1922. (Pp. v + 110.) Price 2*s*. 6*d*. net.

Mathematical Tables. By G. H. Bryan, Sc.D., F.R.S., Professor of Mathematics in the University College of North Wales. London: Macmillan & Co., St. Martin's Street, 1922. (Pp. 28.) Price 3*s*. 6*d*. net.

The Mathematical Theory of Relativity. By A. S. Eddington, M.A., M.Sc., F.R.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Cambridge: at the University Press, 1922. (Pp. ix + 147.) Price 20*s*. net.

Climatic Changes, their Nature and Causes. By Ellsworth Huntington, Research Associate in Geography in Yale University, and Stephen Sargent Visher, Associate Professor of Geology in Indiana University. New Haven: Yale University Press; London: Oxford University Press, 1922. (Pp. 329, with 13 illustrations.) Price 17*s*. 6*d*. net.

The Quantum Theory. By Fritz Reiche, Professor of Physics in the University of Breslau. Translated by S. Hatfield, B.Sc., Ph.D., and H. L. Brose, M.A. London: Methuen & Co., 36 Essex Street, W.C. (Pp. vi + 183, with 15 diagrams.) Price 6*s*. net.

The Theory of Spectra and Atomic Constitution. Three Essays by Niels Bohr, Professor of Theoretical Physics in the University of Copenhagen. Cambridge: at the University Press, 1922. (Pp. vii + 126.) Price 8*s*. 6*d*. net.

Dimensional Analysis. By P. W. Bridgman, Professor of Physics in Harvard University. New Haven: Yale University Press, 1922. (Pp. iii + 112.) Price 25*s*. net.

A Dictionary of Applied Physics. Edited by Sir Richard Glazebrook, K.C.B., D.Sc., F.R.S. In Five Volumes. Vol. III—Meteorology, Metrology, and Measuring Apparatus. London: Macmillan & Co., St. Martin's Street, 1923. (Pp. vii + 839.) Price 63*s*. net.

The Structure of Atoms. By Alfred Stock, Dr. Phil., Dr. Ing., Professor in the University of Berlin. Translated from the Second German Edition by S. Sugden, A.R.C.Sc., A.I.C., Lecturer in Chemistry, Birkbeck College, University of London. London: Methuen & Co., 36 Essex Street. (Pp. vii + 88, with 18 figures.) Price 6*s*. net.

Atomes et Électrons: Rapports et Discussions du Conseil de Physique. Tenu à Bruxelles du 1er au 6 avril 1921 sous les auspices de l'Institut International de Physique Solvay. Publiés par la Commission administrative de l'Institut et MM. les Secrétaires du Conseil. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1923. (Pp. 279.) Price 20 frs.

A Dictionary of Applied Chemistry. By Sir Edward Thorpe, C.B., LL.D., F.R.S. Assisted by Eminent Contributors. Vol. IV. Revised and Enlarged Edition. London: Longmans, Green & Co., E.C.4, 1922. (Pp. viii + 740.) Price 60*s*. net.

Oxidations and Reductions in the Animal Body. By H. D. Dakin, D.Sc., F.I.C., F.R.S. Second Edition. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. ix + 176.) Price 6*s*. net.

An Advanced Course of Instruction in Chemical Principles. By Arthur A. Noyes and Miles S. Sherrill. New York: The Macmillan Company, 1922. (Pp. xviii + 310.) Price 18*s*. net.

A Textbook of Inorganic Chemistry. New and Enlarged Edition. By G. S. Newth, F.I.C., F.C.S. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1923. (Pp. xiii + 772.) Price 8*s*. net.

Practical Plant Biochemistry. By Muriel Wheldale Onslow, formerly Fellow of Newnham College, Cambridge, and Research Student at the John Innes Horticultural Institution, Merton, Surrey. Cambridge: at the University Press, 1923. (Pp. iv + 194.) Price 12*s*. 6*d*. net.

Elementary Geology, with Special Reference to Canada. By A. P. Coleman, M.A., Ph.D., F.R.S., Professor of Geology, University of Toronto, and W. A. Parks, B.A., Ph.D., F.R.S.C., Professor of Palæontology, University of Toronto. London and Toronto: J. M. Dent & Sons, 1922. (Pp. xx + 363, with 197 illustrations.) Price 15*s*. net.

The Andover District: An Account of Sheet 283 of the One-Inch Ordnance Map. By O. G. S. Crawford, B.A. Oxford: at the Clarendon Press, 1922. (Pp. 99, with 15 plates.)

The Inland Lakes of Wisconsin. The Plankton. I—Its Quantity and Chemical Composition. By Edward A. Birge and Chancey Juday, Wisconsin Geological and Natural History Survey. Madison, Wisconsin: Published by the State, 1922. (Pp. ix + 217, with 40 figures.)

Molybdenum Ores. By R. H. Rastall, Sc.D., M.Inst.M.M., F.G.S., Lecturer on Economic Geology in the University of Cambridge. Imperial Institute Monographs. London: John Murray, Albemarle Street, W. (Pp. ix + 86.) Price 5*s*. net.

Geomorphology of New Zealand. Part I—Systematic. An Introduction to the Study of Land-forms. New Zealand Board of Science and Art. Manual No. 3. By C. A. Cotton, D.Sc., F.N.Z.Inst., F.G.S., Professor of Geology, Victoria University College, Wellington. Wellington, N.Z.: Dominion Museum, 1922. (Pp. + 462, with 442 figures.) Price, in paper cover, 18*s*; and bound in cloth, 22*s*. 6*d*.

Pests of the Garden and Orchard, Farm and Forest. By Ray Palmer, F.E.S., and W. Percival Westell, F.L.S. London: Henry J. Drane, Danegeld House, Farringdon Street, E.C.4. (Pp. 412, with 44 plates.) Price 25*s*. net.

Productive Farming. By Kary Cadmus Davis, Ph.D. Fifth Edition, Revised and Enlarged. Philadelphia and London: J. B. Lippincott Company. (Pp. viii + 403 + xxxix.) Price 6*s*. net.

A Summer in Greenland. By A. C. Seward, Master of Downing College, and Professor of Botany in the University of Cambridge. Cambridge: at the University Press, 1922. (Pp. xi + 100, with 29 plates and 2 maps.) Price 7*s*. net.

The Preparation of Plantation Rubber. By Sidney Morgan, A.R.C.S., Visiting Agent for Estates in the East. With a Preface and a Chapter on Vulcanisation, by Henry P. Stevens, M.A., Ph.D., F.I.C., Consulting Chemist to the Rubber Growers' Association in London. London: Constable & Co., 1922. (Pp. xvi + 331, with 66 illustrations.) Price 21*s*.

Propriétés Générales des Sols en Agriculture. Par Gustave André, Professeur à l'Institut Agronomique Agrégé de la Faculté de Médecine. Paris: Librairie Armand Colin, 103 Boulevard Saint-Michel, 1923. (Pp. vi + 184.) Price 5 frs.

The Physiology of Reproduction. By Francis H. A. Marshall, Sc.D., D.Sc., F.R.S. With Contributions by William Carmer, Ph.D., D.Sc., M.R.C.S., L.R.C.P., James Lockhead, O.B.E., M.A., F.R.C.S.E., and Cresswell Shearer, M.D., Sc.D., F.R.S. Second and Revised Edition. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. xvi + 770.) Price 36*s*. net.

The Elasmobranch Fishes. By J. Frank Daniel, Professor of Zoology in the University of California. California: University of California Press, Berkeley, 1922. (Pp. xi + 334, with 260 figures.) Price $5.50.

Les Marées et leur Utilisation Industrielle. Par E. Fichot, Ingénieur Hydrographe en Chef de la Marine. Paris: Gauthier-Villars et Cie., 55 Quai des Grands-Augustins, 1923. (Pp. vi + 246.) Price 9 frs.

Ancient Man in Britain. By Donald A. Mackenzie. With Foreword by G. Elliot Smith, F.R.S. London: Blackie & Son, 50 Old Bailey, 1922. (Pp. xv + 257, with 17 plates.) Price 12*s*. 6*d*. net.

Practical Chemical Physiology. By W. W. Taylor, M.A., D.Sc., Lecturer in Chemical Physiology at the University of Edinburgh. London: Edward Arnold & Co., 1922. (Pp. 71.) Price 5*s*.

Practical Physiology. By E. P. Cathcart, M.D., D.Sc., F.R.S., D. Noel Paton, M.D., LL.D., F.R.S., M. S. Pembery, M.A., M.D., F.R.S. London: Edward Arnold & Co., 1922. (Pp. xii + 344.) Price 18*s*. net, and in two volumes at 10*s*. 6*d*. per volume.

Malay Poisons and Charm Cures. By John D. Gimlette, M.R.C.S., L.R.C.P. Second Edition. London: J. & A. Churchill, 7 Great Marlborough Street, 1923. (Pp. xii + 260.) Price 8*s*. 6*d*. net.

Symbiosis *v.* Cancer. By H. Reinheimer. With a Preface by Sir William Veno. London: Headley Bros., 18 Devonshire Street, Bishopsgate, E.C.2. (Pp. 99.) Price 5*s.* net.

The Essentials of Chemical Physiology. For the Use of Students. By W. D. Halliburton, M.D., LL.D., F.R.S. Eleventh Edition. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1922. (Pp. xi + 343.) Price 8*s.* 6*d.* net.

Protists and Disease. By J. Jackson Clarke, M.B. Lond., F.R.C.S., Senior Surgeon in the Hampstead and North-West London Hospital. London: Baillière, Tindall & Cox, 8 Henrietta Street, Covent Garden, 1922. (Pp. xii + 220, with 1 plate and 61 figures.) Price 15*s.* net.

Eugenical Sterilisation in the United States. By Henry Hamilton Laughlin, D.Sc., Assistant Director of the Eugenics Record Office, Carnegie Institution of Washington, Cold Spring Harbour, Long Island, New York. Chicago: Psychopathic Laboratory of the Municipal Court of Chicago, 1922. (Pp. xxiii + 502, with 15 figures and 3 charts.)

Handbook of Chemical Engineering. Prepared by a Staff of Specialists, Donald M. Liddell, Editor-in-Chief, Consulting Engineer and Economist, Member A.I.M.E., M.M.S.A. In Two Volumes. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp., Vol. I, xi + 518; Vol. II, 519–1108, with illustrations.) Price 40*s.*

Shield and Compressed Air Tunnelling. By B. H. M. Hewett, M.Am.Soc.C.E., M.Inst.C.E., and S. Johannesson, M.Am.Soc.C.E. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. x + 465, with 170 figures.) Price 25*s.* net.

Electric Transients. By Carl Edward Magnusson, A. Kalin, J. R. Tolmic. New York: McGraw-Hill Book Co., 370 Seventh Avenue; London: 6 and 8 Bouverie Street, E.C.4, 1922. (Pp. viii + 193, with 161 figures.) Price 12*s.* 6*d.* net.

Étude sur la Ballon Captif et les Aéronefs Marins. Par le Commandant Charles Lafon. Paris: Gauthier-Villars et Cie., 55 Quai des Grands-Augustins, 1922. (Pp. vi + 203.) Price 20 frs.

Mechanical Testing. A Treatise in Two Volumes. By R. G. Batson, M.Inst.C.E., M.I.Mech.E., and J. H. Hyde, C.M.Inst.C.E., M.I.A.E., A.M.I.Mech.E. Vol. II—Testing of Prime Movers, Machines, Structures, and Engineering Apparatus. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1922. (Pp. xi + 446, with 313 figures.) Price 25*s.* net.

Cements and Artificial Stone. A Descriptive Catalogue of the Specimens in the Sedgwick Museum, Cambridge. By the late John Watson, Hon. M.A., F.G.S. Edited by R. H. Rastall, Sc.D., M.Inst.M.M. Cambridge: W. Heffer & Sons, 1922. (Pp. xiii + 131.) Price 6*s.* net.

Textbook on Wireless Telegraphy. Vol. II—Valves and Valve Apparatus. By Rupert Stanley, B.A., LL.D., M.I.E.E. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1923. (Pp. xi + 394, with 249 figures.) Price 15*s.* net.

On Elementary Principles of Lighting and Photometry. By John W. T. Walsh, M.A., M.Sc., A.M.I.E.E., F.Inst.P. With a Foreword by Sir J. E. Petavel, K.B.E., F.R.S., D.Sc., and 85 diagrams by Frederick G. H. Lewis. London: Methuen & Co., 36 Essex Street, W.C. (Pp. xvi + 220.) Price 10*s.* 6*d.* net.

Letters of a Radio-Engineer to His Son. By John Mills, Engineering Department, Western Electric Company. London: George Routledge & Sons, 68 Carter Lane, E.C., 1922. (Pp. 265, with 136 figures and 12 plates.) Price 10*s*. 6*d*. net.

Abstract-Bulletin of Nela Research Laboratory, National Lamp Works of General Electric Company, Cleveland, Ohio. By Edward P. Hyde, Director. Vol. I, No. 3. Published by the Research Department, 1922. (Pp. ix + 303–521.)

La Houille Blanche. Par Henri Cavaillés, Professeur au Lycée de Bordeaux. Paris: Librairie Armand Colin, 103 Boulevard Saint-Michel, 1923. (Pp. vi + 215, with 8 maps and 4 figures.) Price 5 frs.

Human Character. By Hugh Elliot. London: Longmans, Green & Co., 39 Paternoster Row, 1922. (Pp. xvi + 272.) Price 7*s*. 6*d*. net.

The Measurement of Emotion. By W. Whately Smith, M.A., with a Foreword by W. Brown, M.D., D.Sc. London: Kegan Paul, Trench, Trübner & Co., 1922. (Pp. 184.) Price 10*s*. 6*d*. net.

Tractatus Logico-Philosophicus. By Ludwig Wittgenstein, with an Introduction by Bertrand Russell, F.R.S. London: Kegan Paul, Trench, Trübner & Co., 1922. (Pp. 189.) Price 10*s*. 6*d*. net.

Colour Vision. A Discussion of the Leading Phenomena and their Physical Laws. By W. Peddie, D.Sc., V.P.R.S.E., University of St. Andrews. London: Edward Arnold & Co., 1922. (Pp. xii + 208.) Price 12*s*. 6*d*. net.

The New Psychology and the Parent. By H. Crichton Miller, M.A., M.D., Editor "Functional Nerve Disease." London: Jarrolds, Ltd. (Pp. 255.) Price 6*s*. net.

Die Lehre vom Diskreten Raum in der Neueren Philosophie. Von Nikola M. Poppovich, Dr. Phil. Vienna and Leipzig: Wilhelm Braumoller, Universitäts-Verlagsbuchhandler, Ges. (m.b.)H., 1922. (Pp. 89.)

The Principles of Logic. By F. H. Bradley, Fellow of Merton, Oxford. Second Edition. Revised, with Commentary and Terminal Essays. London: Oxford University Press, 1922. (Pp., Vol. I, xxviii + 388, Vol. II, 389–739.) Price 36*s*. net.

Life Contingencies. By E. F. Spurgeon, F.I.A. Published by the authority and on behalf of the Institute of Actuaries by Charles and Edwin Layton, Farringdon Street, E.C.4. London: 1922. (Pp. xxvi + 477.)

Discoveries and Inventions of the Twentieth Century. By Edward Cressy. Second Edition. Revised and Enlarged. London: George Routledge & Sons; New York: E. P. Dutton & Co., 1923. (Pp. xxiii + 458, with 342 figures.) Price 12*s*. 6*d*. net.

The greater part of this book has been wholly rewritten. Chapter XII, which gives some account of the achievements of modern chemistry, is new, while Chapter XVIII of the old edition has been omitted, since it was not the wish of the author to give an account of the subject—Ships of War and their Weapons—which would inevitably be imperfect.

Annuaire pour l'An 1923, publié par le Bureau des Longitudes avec des Notices Scientifiques. Paris: Gauthier-Villars et Cie., 55 Quai des Grands-Augustins. (Pp. viii + 654.) Price 6.50 frs.

Les Hélicoptères, Recherches Expérimentales sur le Fonctionnement le plus général des Hélices. Études sur la Mécanique de l'Hélicoptère. Par W. Margoulis, Ancien Directeur du Laboratoire Eiffel. Paris: Gauthier-Villars et Cie., 55 Quai des Grands-Augustins, 1922. (Pp. x + 90.) Price 10 frs.

Group Psychology and the Analysis of the Ego. By Sigm. Freud, M.D., LL.D. Authorised Translation by James Strachey. London: The International Psycho-Analytical Press, 1922. (Pp. 134.) Price 7*s.* 6*d.* net.

The Outline of History. Being a Plain History of Life and Mankind. By H. G. Wells. Written originally with the advice and editorial help of Dr. Ernest Barker, Sir H. H. Johnston, Sir E. Lankester, and Prof. Gilbert Murray, and illustrated by J. F. Horrabin. The Definitive Edition revised and rearranged by the Author. London and New York: Cassell & Co. (Pp. xix + 631, with 209 illustrations and maps.) Price 21*s.*

Causes and Consequences. By Sir Bamfylde Fuller, K.C.S.I., C.I.E. London: John Murray, Albemarle Street, W., 1923. (Pp. x + 291.) Price 12*s.* net.

The Biology of Death. Being a Series of Lectures delivered at the Lowell Institute in Boston in December 1920. By Raymond Pearl, The Johns Hopkins University. Philadelphia and London: J. B. Lippincott Company. (Pp. 75.) Price 10*s.* 6*d.* net.

Injury, Recovery, and Death, in Relation to Conductivity and Permeability. By W. J. V. Osterhout, Ph.D., Professor of Botany, Harvard University. Philadelphia and London: J. B. Lippincott Company. (Pp. 259.) Price 10*s.* 6*d.* net.

An Introduction to the Psychology of Religion. By Robert H. Thouless, M.A., Fellow of Corpus Christi College, Cambridge. Cambridge: at the University Press, 1923. (Pp. iv + 286.) Price 7*s.* 6*d.* net.

Les Origines de la Famille et du Clan. Par James George Frazer, Traduit de l'Anglais par La Comtesse Jean de Pange. Paris: Paul Geuthner, 13 Rue Jacob, 1922. (Pp. 185.)

Psychology and Politics, and other Essays. By the late W. H. R. Rivers, M.D., D.Sc., LL.D., F.R.S. With a Prefatory Note by G. Elliot Smith, F.R.S., and an appreciation by C. S. Myers, F.R.S. London: Kegan Paul, Trench, Trübner & Co.; New York: Harcourt, Brace & Co., 1923. (Pp. vii + 181.) Price 10*s.* 6*d.* net.

Conflict and Dream. By the late W. H. R. Rivers, M.D., D.Sc., LL.D., F.R.S., With a Preface by G. Elliot Smith, F.R.S. London: Kegan Paul, Trench, Trübner & Co.; New York: Harcourt, Brace & Co., 1923. (Pp. xi + 195.) Price 12*s.* 6*d.* net.

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