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MEMOIRS AND PROCEEDINGS

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NOTE.

The authors of the several papers contained in this volume are themselves accountable for all the statements and reasonings which they have offered. In these particulars the Society must not be considered as in any way responsible.

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MEMOIRS.

PROCEEDINGS.

Manchester Memoirs, Vol. xlviii. (1903), *No.* **1**.

I. On the Resolution of Elementary Substances into their Ultimates and on the Spontaneous Molecular Activity of Radium.

By Henry Wilde, D.Sc., F.R.S.

Received and read October 6th, 1903.

In the several papers which I have read before the Society during the past twenty-five years on the genesis of elementary substances and on the multiple proportions of their atomic weights,[1] certain gaps appeared in the several series shown in my Tables which have since been filled up by the newly discovered elements, scandium, germanium, helium, argon, neon, krypton and xenon.

The remarkable properties of the new element Radium bring about further realizations of the predictions made in my earlier papers, and afford sufficient reason for recapitulating some of the statements contained therein and for reproducing my several Tables in connexion with the present communication to the Society.

In these papers it is assumed (1) that elementary species have been formed by successive condensations of the cosmic nebular substance into the typical hydrogen molecules H, H2, H3, H4, H5, H6, H7 ; (2) that the series of elements have been formed by the successive condensations of the typical molecule at the head of each series in multiple proportions ; (3) that the atomic weights are multiples of the typical molecule at the head of each

[1] "On the Origin of Elementary Substances and on some new Relations of their Atomic Weights," *Proc. Lit. and Phil. Soc. Manchester*, Vol. XVII., pp. 218, 1878. *Chem. News*, Vol. XXXVIII., pp. 66, 96, 107, 1878. *Manchester Memoirs*, Vol. XXX., 1887. *Ibid.*, Vol. XXXIX., 1895. *Ibid.*, Vol. XLVI., 1902.

series ; (4) that the ordinal number of the typical molecule determines the quantivalence and analogous properties of each series of elements under it.

I have shown that if the second member of the series Hn (Na = 23) be multiplied successively by an arithmetical series, then will the products, minus the atomic weight of the first member (Li = 7), be the atomic weights of the elements of that series.

Hn.

0 . 0 . 7	Li	= 7
1 × 23 . 0 =	Na	= 23
2 × 23 − 7 =	Ka	= 39
3 × 23 − 7 =	Cu	= 62
4 × 23 − 7 =	Rb	= 85
5 × 23 − 7 =	Ag	= 108
6 × 23 − 7 =	Cs	= 131
7 × 23 − 7 =	—	= 154
8 × 23 − 7 =	—	= 177
9 × 23 − 7 =	Hg	= 200

Similarly, the multiplication of the atomic weight of the second member of the series H2n (Mg = 24), the products, minus the atomic weight of the first member (Gl = 8), give the atomic weights of this series of elements.

H2n.

0 . 0 . 8 =	Gl	= 8
1 × 24 − 0 =	Mg	= 24
2 × 24 − 8 =	Ca	= 40
3 × 24 − 8 =	Zn	= 64
4 × 24 − 8 =	Sr	= 88
5 × 24 − 8 =	Cd	= 112
6 × 24 − 8 =	Ba	= 136
7 × 24 − 8 =	—	= 160
8 × 24 − 8 =	—	= 184
9 × 24 − 8 =	Pb	= 208

By multiplying in like manner the atomic weight of the second member of H3n (Al = 27), the products, minus the atomic weight of the first member (C = 12), are the atomic weights of the members of this series.

H3n.

$$
\begin{aligned}
0\ .\ \ 0\ .\ 12 &= C = 12 \\
1\times 27\ .\ \ 0 &= Al = 27 \\
2\times 27 - 12 &= Sc = 42 \\
3\times 27 - 12 &= Ce = 69 \\
4\times 27 - 12 &= Ga = 96 \\
5\times 27 - 12 &= Yt = 123 \\
6\times 27 - 12 &= In = 150 \\
7\times 27 - 12 &= Er = 177 \\
8\times 27 - 12 &= Tl = 204 \\
9\times 27 - 12 &= Th = 231
\end{aligned}
$$

The members of the series H7n in my Table of Elements, arranged with their atomic weights in multiple proportions, now stand in the following order:—

H7n.

Ne = 1 × H7 = 7
N = 2 × H7 = 14
Ar = 3 × H7 = 21
Kr = 6 × H7 = 42
Xe = 9 × H7 = 63
Si = 4 × H7 = 28 or 5 × H7 = 35*
Fe = 8 × H7 = 56 . Mn 55 . Ni 58 . Co 58
Pd = 15 × H7 = 105 . Pd 105·6 . Rh 104·4 . Ru 104·4 . Da .
Au = 28 × H7 = 196 . Pt 197 . Ir 198 . Os 198

The position of carbon in the series H3n is confirmed by its exact numerical relations with aluminium, thallium and thorium, and the multiple proportions of the

* Regnault, *Annales de Chimie et de Physique*, Tome 63, pp. 24-31, 1861.

atomic weights of the intermediate members of the same series. The accepted valencies of these members, as I have already stated, are still open to revision, and they will be found ultimately to agree with the values shown in my Tables. The constitution and position of carbon at the head of the series H3n also give support to the tetrahedral concept of van't Hoff* and Le Bel† in regard to this element, as the tetrahedron is necessarily correlated with tridimensional space in the stereo-piling of the carbon molecule $4 \times H3 = C$.

An examination of the atomic weights of the positive and negative series Hn and H2n in Table I. will show that the differences between the theoretic and experimental atomic weights (excluding radium provisionally), when distributed among the twenty-four members of these series, amount to less than half of 1 per cent. of the actual determinations. It is also interesting to note (1) the common numerical difference of 4 between the monatomic halogens and the alkaline metals in homologous positions, and (2) the common difference of 8 between the diatomic oxygen series and the alkaline earth metals in similar positions, (3) the natural arrangement and extension of the well-known triads in which the sum of the atomic weights of the extremes is equal to double the atomic weights of the means in these series, (4) that the highest places in my complete Table are filled up by well-known elements of the greatest atomic weights.

From the definite multiple relations which the atomic weights of mercury, lead and thorium have to those of the lower members of their respective series, for the same number of elementary condensations, there is abundant reason for concluding that no elements exist of higher

* *Archives Néerlandaises des Sciences*, Tome IX., pp. 445-454, 1874.

† *Bull. de la Soc. Chim.*, 1874.

atomic weights than those shown in each series of the Table.

The electro-positive series H2n has long been remarkable for the property of phosphorescence which some of its lower members possess above those of the other series of elements. Thus, calcium sulphide (Canton's phosphorus or Balmain's paint), and barium sulphide (Bolognian phosphorus) become luminous when exposed to the action of solar or electric light, and retain their luminescence for a considerable time after the source of light has been removed.

Radium has been shown by its discoverers, M. and Mme. Curie, to be the next higher member of the calcium, strontium and barium series (H2n) of alkaline earth metals, and that its halogen compounds are permanently self-luminous.

I have already indicated the remarkable interruption in the regularity of the multiple series H2n through the absence of elements with atomic weights 160 and 184 respectively, the numerical order being resumed with the atomic weight of lead 208. These gaps in the series are the more striking from their being exactly paralleled by the absence of two members in homologous positions in the series Hn, with atomic weights 154 and 177, the multiple order being resumed by the atomic weight of mercury 200. These lacunæ obviously indicate the existence of undiscovered elements, or of elements transmuted or in the process of transmutation.

As there is only one place vacant higher in the series H2n for an analogue of calcium, strontium and barium, alternating with zinc, cadmium and lead, radium is identified as the tenth elementary condensation of H2, with an atomic weight of 184, and a specific gravity of 4·8, as shown in my Table.

In my former papers read before the Society[1] and in a note which was presented to the French Academy of Sciences,[2] I have shown that helium is the typical element of the series H2n with an atomic weight of 2 (He = 2); a value now adopted by French chemists in the Table of atomic weights published in the *Annuaire du Bureau des Longitudes.*

In discussing the question of the transmutable nature of the chemical elements at the end of my first paper published in the Proceedings of the Society and in the Chemical News in 1878, the following remarks occur which are now of some interest.

"The numerical relations of the atomic weights to "which I have directed attention, and the brief outline of "a theory of the origin of elementary species which I have "founded upon them, give new force to the doctrine of the "transmutable nature of elementary substances. But "when the synthetical formation of organic compounds is "regarded as the greatest triumph of modern chemical "science, the problem of building up the higher elements "from the lower may well be deemed insoluble, as they "have been formed under cosmical conditions with which "we have little or no acquaintance. Very different, "however, is the aspect of the problem of resolving the "higher elements of each series into their respective types "or into hydrogen. For just as by the application of heat "the higher members of homologous series are resolved, "through their lower members, into their ultimates, so "may it be expected that the elements themselves will, "in their turn, give way to more powerful instruments of "analysis."

I have made many experiments in the direction above

[1] *Manchester Memoirs,* Vol. XL., p. 3, 1895. *Ibid.*, Vol. XLVI., 1902.
[2] *Comptes Rendus,* Tome 125, pp. 649, 707, 1897.

indicated, the most interesting of which was the attempt to effect the mutual transmutations of argon and nitrogen by the changes manifested in their spectra when these elements were sparked under different conditions of pressure and temperature and with electrodes of different metals. The experiments are described in a note presented to the French Academy of Sciences in 1897[1]. While the results of these attempts at transmutation were entirely negative, science was advanced by them through my discovery of new spectral lines of oxygen and of thallium[2], the new line 6560 of thallium establishing a more simple relation of the spectra of the elements and their atomic weights than those shown by any other of the series of elementary substances[3].

Through the recent inventions of the radio-electroscope and the improved methods of producing extremely low temperatures, Professors Rutherford, Soddy and Ramsay have shown that helium is spontaneously and continuously evolved from radium[4]. Now in this result, we have a clear instance of the resolution of the higher element X = 184 into the lower typical molecule H2 of the same series as prevised in my paper read before the Society in 1878, and shown in the Table subjoined to my subsequent paper published by the Society in 1902[5]. The resolution of radium into helium confirms the positions of both these elements in my Table, and also the wide separation of helium from the argon family with which it has hitherto been classified solely on account of its property of chemical inertness.

In view of the order in which other instances of trans-

[1] *Comptes rendus*, Tome 125, p. 649, 1897.

[2] *Ibid.*, p. 708.

[3] *Proc. Roy. Soc.*, Vol. 53, pp. 369-372.

[4] *Nature*, July 16th, 1903. *Proc. Roy. Soc.*, July 28th, 1903.

[5] *Manchester Memoirs*, Vol. XLVI., (14), 1902.

mutation from higher into lower members of each series may manifest themselves, it is not to be expected that the transmutation of the higher members of different series into each other will be accomplished, *e.g.*, mercury and lead into gold, according to the notions of the alchemists.

It would be premature to speculate upon the characteristics of the missing element X = 160 of the series H2n in my Table or upon those of X = 154 in the series Hn, but the missing member X = 177 of this series, homologous in position with radium = 184, has special features of interest, as it has very recently been shown by Strutt that an intensely radio-active emanation is given off by mercury[1]. It would be of interest to know if this emanation—either from the metal itself or from the naturally occurring minerals containing it—would lead to the discovery of X = 177, or be resolved into the typical element, H1 (hydrogen), as in the parallel case of radium into helium in the series H2n.

I have stated in a former paper the high probability there is that some, if not all, of the typical elements at the head of each series exist in a state of gas[2], and the gaseous character of the highest of these elementary molecules (neon = H7) favours the supposition that the remaining undiscovered typical elements H6, H5, H4, H3, are also in the gaseous condition at ordinary temperatures. It would be of further interest to know if the emanations from thorium, uranium and bismuth would resolve themselves into the elementary molecules H3, H4, and H5, respectively. From the extremely minute quantities of these elementary bodies to be found in nature, their detection may only be possible by observation of their characteristic spectra as in the case of helium in the emanation from radium.

[1] *Phil. Mag.*, July, 1903, p. 113.

[2] *Manchester Memoirs*, Vol. XL., p. 7, 1896.

In my paper "On the Indefinite Quantitative Relations of the Physical and Chemical Forces" read before the Society in 1896,[1] and in the lecture delivered before the Society in 1902,[2] it was demonstrated that the principle of the conservation of static and dynamic forces is subordinate to the hyperphysical principle of the incommensurableness of these forces, and that the conservation of force rested upon a different foundation to that of the conservation of substance the creation or annihilation of which is unthinkable.

The instances of incommensurableness given included (1) the Archimedian principle of the indefinite increase of the mechanical forces on which most of the mechanical arts depend; (2) the indefinite increase of the electric and magnetic forces from quantities indefinitely small, on which the modern electrical engineering industry is founded; (3) the indefinite increase of the electro-chemical forces, on which the electrolytic process of refining copper on a large scale is now conducted. It was further shown in my lecture referred to that, the Cartesian dogma of the universal conservation of *motion* and *rest* (modernised under the name of *actual* and *potential* energy) was disproved by the creation of energy through the explosion of endothermic substances and by other examples; and, further, that the power of spontaneous motion can no longer be held to be the exclusive attribute of the organized forms of the hydro-carbon compounds. An illustrative instance of the creation of molar and molecular motion was given in the explosion of 4·5 lbs. of gun-powder, whereby 2200 foot-tons of energy would be added to the sum previously existing in the universe.

Now MM. Curie and Laborde have shown that radium

[1] *Manchester Memoirs*, Vol. XL., pp. 61-71.

[2] *Ibid.*, Vol. XLVI., (14), p. 34.

possesses the property of maintaining constantly a temperature higher than that of its surroundings, and of continuously and spontaneously emitting heat sufficient to melt its own weight of ice per hour.

Reduced to its mechanical equivalent, the amount of heat continuously evolved from 1lb. of radium salt would be = 48·94 foot-tons per hour (142° F. × 772 J. = 109624 lbs. = 48·94 foot-tons).

Comparing this result with the energy created by the explosion of 4·5 lbs. of gunpowder we have 4·5 × 48·94 = 220 foot-tons of energy evolved from 4·5 lbs. of radium per hour or 2200 foot-tons in 10 hours, the equivalent of the energy created by the explosion of 4·5 lbs. of gunpowder. But the same amount of energy has been spontaneously evolved from radium for thousands of years past and continues to increase the sum total of all the motions in the universe, notwithstanding the Cartesian dogma of the conservation of motion to the contrary.[1]

Although radium is the first self-evident instance of an inorganic substance having the power of spontaneous molecular motion, without those antecedents and concomitants which induce in the mind the idea of causation, the emanations from other elements of high atomic weight indicate that similar manifestations of spontaneous motion, but of lower amount, could be obtained from these elements.

Notwithstanding that the power of spontaneous (endothermic) motion which radium possesses is so demonstrably evident, the idea has been put forward that the energy so manifested is derived in some way unknown from sources external (exothermic) to itself. We have in this idea another significant instance of the survival of one

[1] *Principia Philosophiæ*, Pars 2, § XXXVI., 1643.

of the primitive modes of thinking described in the following passage from my lecture referred to: "Just as "the spasmodic and capricious movements of the "organised forms of the hydro-carbon compounds create "in the mind the idea of spontaneous motion, *acting from* "*within*, so the regular and rhythmical motions of "inorganic substances, under constant conditions, induce "in the early stages of man's intellectual development, the "idea that such bodies only move by impulse, *acting from* "*without*, and of necessity."[1]

An enquiry into the origin of the various ideas of Causation is a subject of great philosophical interest, but it has not yet received that amount of attention which its importance deserves. The principles involved cannot be discussed in this paper, but with the object of giving a direction to the enquiry I here present in graphic form (Table II.), the striking parallelism, or the actual identity, of modes of Causation in natural science and in natural religion.

All the modes of causation in the natural sciences as therein set forth were originated, and have been adopted by men who have made the greatest and most numerous contributions to natural knowledge within historical periods. On the other hand, the origins of the homologous modes of causation in natural religions are lost in the mists of a remote antiquity, but these can now be clearly defined by comparison with the analogous modes of causation in the natural sciences.

All the exalted ideals around which the homage and affection of humanity have crystallized have been born into, and have made one or other of the modes of causation in religion as therein set forth, with their respective

[1] "On the Evolution of the Mental Faculties in Relation to some Fundamental Principles of Motion." *Manchester Memoirs*, Vol. XLVI., (10), pp. 1-34, 1902.

cosmogonies, the foundation upon which their religio-ethical systems have been established. However much some of these systems fall short of the requirements of modern knowledge and of advancing civilization, they have been of supreme value in the education of a world wherein slavery and cannibalism are still flourishing institutions. Such systems are, moreover, the evolutionary steps towards the realization of that ideal state of society in which, in the fundamentals of religion as well as of science, all mankind will ultimately be of one heart and of one mind.

DEFINITIONS.

I. NATURAL SCIENCE is the abstract knowledge of the nature and properties of things as distinguished from the knowledge of their uses which constitutes Art.

II. NATURAL RELIGION is man's conscious recognition of purposive intelligence and adaptability in the universe of things, similar to that exercised by himself, and on which he is dependent for his continued existence and well being, and with which he endeavours to live in harmonious relations. The various acts which man performs to express this recognition and sense of dependence constitute the different forms of religious Worship.

COROLLARIES.

1. Natural science, as embodied in ancient and modern cosmogonies, is the antecedent foundation of natural religion and of all other religions.

2. Natural religion and natural science are as necessarily correlated as the dimensional properties of space and of substance.

3. Just as man's ideas of causation in the natural sciences are in conformity or otherwise to the real nature of things, so will his ideas of causation agree or disagree correlatively in natural religion and in all religions.

TABLE I.

Table of Elementary Substances, with their Atomic Weights in Multiple Proportions, 1878—1894—1902—1903.

	+ Hn —		+ H2n —		H3n	H4n	H5n	H6n	H7n	
1	H = 1		He = 2						Ne = 7	
2	Li = 7 · · · · 7* 0·59†		Gl = 8 · · · · 9·2 1·64? 1·3‡		C = 12 · · · · 12 1·71§	— = 16	B = 10 · · · · 11 2·63	— = 18	N = 14 Ar = 21 Kr = 42 Xe = 63	
3	Na = 23 · · · · 23 0·98	F = 19 · · · · 19	Mg = 24 · · · · 24 1·74	O = 16 · · · · 16	Al = 27 · · · · 27 2·56	— = 32	P = 30 · · · · 31 1·82	— = 36	Si = 35 28 : 35 2·49	
4	K = 39 · · · · 39 0·86	Cl = 35 · · · · 35·5 1·3	Ca = 40 · · · · 40 1·58	S = 32 · · · · 32 2·05	Sc = 42 · · · · 44 3·4	Ti = 48 · · · · 48 4·1‡	V = 50 · · · · 51·2 5·5	Cr = 54 · · · · 52·4 7·3	Fe = 56 Mn = 56 Ni = 56 Co = 56	56—8·14‖ 55—8·00 58—8·66 58—8·96
5	Cu = 62 · · · · 63·3 8·9		Zn = 64 · · · · 65 7·2		Ce = 69 92 : 141 6·5	Ge = 72 · · · · 72·7 5·47	As = 75 · · · · 75 5·63			
6	Rb = 85 · · · · 85 1·52	Br = 81 · · · · 80 3·0	Sr = 88 · · · · 87·5 2·54	Se = 80 · · · · 79·4 4·8	Ga = 96 · · · · 70 5·95	Zr = 92 · · · · 90 4·15? 5·4‡	Nb = 95 · · · · 94 6·67	Mo = 96 · · · · 96 8·6		
7	Ag = 108 · · · · 108 10·6		Cd = 112 · · · · 112 8·69		Y = 123 61·7 : 89·5 8·1‡	Sn = 116 · · · · 116 7·29	Sb = 120 · · · · 120 6·72		Pd = 105 Rh = 105 Ru = 105 Da = 105	105·6—12·0 104·4—11·2 104·4—11·4 ... ...
8	Cs = 131 · · · · 132 1·88	I = 127 · · · · 127 4·95	Ba = 136 · · · · 137 3·75	Te = 128 · · · · 128 6·3	In = 150 75·6 : 113·4 7·42	La = 140 · · · · 139 6·7	*x* = 140 · · · · · · 8·15‡	*x* = 144 · · · · · · 10·0‡		
9	*x* = 154 · · · · · · 12·2‡		*x* = 160 · · · · · · 10·13‡		Er = 177 · · · · 170·6 9·4‡	*x* = 164 · · · · · · 9·11‡	Po? = 165 · · · · · · 8·30‡			
10	*x* = 177 2·2‡		Ra = 184 · · · · · · 4·8‡		Tl = 204 · · · · 204 11·85	D = 188 · · · · 95 8·0‡	Ta = 185 · · · · 182 10·78? 9·8‡	W = 186 · · · · 184 18·26		
11	Hg = 200 · · · · 200 13·6		Pb = 208 · · · · 207 11·44		Th = 231 · · · · 231·4 11·23	U = 240 · · · · 240 18·4	Bi = 210 · · · · 210 9·83		Au = 196 Pt = 196 Ir = 196 Os = 196	196—19·34 197—21·50 198—22·42 198—22·48

*Accepted Atomic Weights. †Specific Gravities. ‡Estimated. §Anthracite. ‖Electro-deposited.

*** The accepted atomic weights are taken from the standard works and tables of Wurtz, Roscoe and Schorlemmer, J. P. Cooke, F. W. Clarke, and Watts' "Dict. Chem. Supp.," p. 247—Atomicity.

TABLE II.

MODES OF CAUSATION IN NATURAL SCIENCE AND IN NATURAL RELIGION.

1. MONOELECTRIC spirit, imponderable fluid.—Animistic concept originated by Thales, Æpinus, and Franklin to explain electrical phenomena.	1. MONOTHEISM.—Judaism and Mohammedanism.—Animistic and anthropomorphic concept of the creative intelligence and the embodiment of goodness.
2. DUOELECTRIC spirits, imponderable fluids.—Animistic concepts originated and upheld by Dufay, Poisson, Coulomb and others to explain the antithetical attractions and repulsions of electrified and magnetised bodies.	2. DUOTHEISM.—Zoroastrianism and Neo-Judaism.—Animistic and anthropomorphic concepts of the antithetical principles of good and evil (Ormazd and Ahriman).
3. TRIELECTRIC spirits, imponderable fluids.—Animistic concepts originated and promulgated by eighteenth century philosophers under the names of positive, neutral, and negative electricities.	3. TRITHEISM. — Hinduism. — The Hindu Trinity.—Brahma creator, Vishnu preserver, and Shiva destroyer.
4. POLYCORPUSCULAR spirits, imponderable fluids and entities.—Concepts of seventeenth century philosophers to explain the causes of the phenomena of light, heat, cold, magnetism, electricity, sound, and vitality.	4. POLYTHEISM.—Egyptian, Grecian, Roman, Scandinavian and Buddhistic religions.—Animistic and anthropomorphic concepts and embodiments of individual principles of all things.
5. PANTRANSMUTATIVE forces and substances.—Concepts originated and upheld by Bacon, Locke, Rumford, Young, Davy, Carnot, Faraday, Joule, Mayer, Grove and others. The transmutation of chemical substances, compound and elementary, by ancient and modern chemists.	5. PANTHEISM.—Brahmanism, Brunoism and Spinozaism.—Naturalistic concepts identifying the all-pervading and transcendental intelligence manifested throughout the universe with the attributes and modes of the infinite substance of the universe itself.

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II. Notes on Fossil Plants from the Ardwick Series of Manchester.

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Received and read October 6th, 1903.

The productive beds of the great South Lancashire Coalfield consist, for the most part, of Middle and Lower Coal Measures. The fossil floras of these divisions have been described by Kidston[1], Salter[2], and others. In the South-East portion of the coalfield other beds occur which have long been known to belong to a higher horizon than the Middle Coal Measures[3], and which constitute the highest Carboniferous beds in Lancashire. These are overlain by a considerable thickness of Permian and Triassic rocks, except on the East side of Manchester, where they form an inlier of coal measures, surrounded on all sides by newer beds. This inlier has been often spoken of as the Manchester coalfield, and it presents many points of geological interest. In the upper beds a remarkable series of bands of Spirorbis limestone occurs,

[1] Kidston ('92).

[2] Salter ('62) and ('64).

[3] See Brockbank and De Rance ('91), p. 282.

The numbers in parentheses after the Authors' names denote the year of publication of the memoir, to which reference will be found in the bibliography at the end of this paper.

often of three feet or more in thickness, and belonging to at least six different horizons[1]. In the lower portion several coal seams occur. Both the limestones and coals have formerly been worked at Ardwick, Bradford, and other localities on the East side of Manchester. On the West side the coals have also been worked below the Permian and Triassic rocks at Pendleton, Patricroft, and other places.

This portion of the Lancashire coalfield has been ascribed for many years to the Upper Coal Measures.[2] The geology of this district has been fully described by Williamson[3], Binney[4], Hull[5], and others[6], and I do not propose to deal further with this subject, except in regard to the evidence which the fossil plants present as to the horizon of these beds in the Upper Carboniferous. Before dealing with the previous records of plants from this coalfield, I may, however, quote a table and two sections taken from Professor Hull's[7] memoir, to show the order of the horizons from which the plants were obtained.

		Feet.
Upper Coal Measures (Manchester) 2,013.	Limestone series	600
	From the limestone to Openshaw coal	600
	From the Openshaw coal to the Yard coal.........	485

[1] See Hull ('64) p. 35, and the bibliography at the end of this paper.

[2] Binney ('68)[1]; Hull ('62), p. 33, and ('81), pp. 199 and 214; Brockbank and de Rance ('91), and other papers given in the bibliography.

[3] Williamson ('36).

[4] Binney ('41)[1] and ('68)[1].

[5] Hull ('62), p. 33 and ('64).

[6] See bibliography.

[7] Hull ('64), pp. 35 and 37. For sections at Patricroft, see Hull ('62), p. 17; at Pendleton, see Binney ('41)[3], p. 161.

Ardwick Limestone Series at Ardwick.

	Ft.	In.
Boulder clay and sand	36	0
Red sandy loam, shales, and clay	84	0
Limestone (Yard Mine)	3	3
Brown and shaley clay	4	9
Limestone (½ Yard Mine)	2	0
Reddish shale and clay	18	0
Blue clay	4	0
Sandstone	24	0
Shale with joints	18	6
Black Lias and black-band ironstone with *Anthracomya*	0	6
[1] Coal and bass	1	6
Strong clay	9	6
[2] *Limestone* (Great Mine) in various beds	6	6

Bradford and Clayton Coal Series at Bradford Colliery.

200 yards below Ardwick Series.

	Ft.	In.
Openshaw Mine ...from 2ft. 6in. to	3	0
Strata ...(about)	135	0
Charlotte Mine ...from 1ft. 6in. to	2	0
Strata	210	0
Three-quarters Mine	1	7
Strata	15	0
Four feet Mine (Main coal)	3	10
Strata	108	0
Yard Mine (variable) ...1ft. 5in. to	4	0
Strata with New Smut coal, 1ft. 4in.	210	0
Two foot coal	2	0
Strata	120	0
Coal	0	10

[1] Also known as the Bassey Mine; see Binney (**'62**).

[2] Also known as the Main or 3 yards Limestone; see Binney (**'62**).

Fossil plants from the Manchester Coalfield have been recorded by Williamson, Phillips, J. W. Salter, and especially by E. W. Binney. It has been thought, however, that several of these are worthy of fuller description, and that a revision of the determinations would be an advantage, for a considerable interval has now elapsed since the collections were made. The increase in our knowledge of Carboniferous plants during the last forty years has been so great that several of the original determinations have proved to be inconclusive. The revision of the nomenclature has also made it possible to compare this flora more accurately with that of other districts, and to throw light on the position of the Manchester Coalfield in the Upper Carboniferous. Further, the increase in the size of the City of Manchester during the last few decades, and the fact that both the limestones and coals, formerly largely worked, are now nearly, or entirely, exhausted,[1] makes it improbable that further specimens will be obtained except under very exceptional circumstances.

Of the collections which I have examined, that of the late E. W. Binney is the most complete. It was presented to the Woodwardian (now known as the Sedgwick[2]) Museum, Cambridge, by Mr. J. Binney, in 1892, together with a large and historic collection of sections of Carboniferous plants, and other specimens. Most, but not all, of the Ardwick specimens recorded by Binney have been recognised.

I am unaware of the whereabouts of the specimens

[1] I am informed by Mr. Mark Stirrup, to whom I am much indebted for information concerning this coalfield, that the limestones are no longer worked, and that apparently only one coal mine is at present working, and that in a somewhat doubtful horizon.

[2] The University Geological collections at Cambridge, formerly known as the Woodwardian Museum, have recently been removed to new buildings erected to the memory of Adam Sedgwick, which will be known as the Sedgwick Memorial Museum

recorded by Williamson, and by Salter. The latter are not at the Jermyn Street Museum, as I have ascertained by several visits; although some of Salter's specimens, from the Middle Coal Measures of Lancashire, are preserved there.

There are also several specimens in the Manchester Museum, Owens College, which, by the kindness of the Director (Dr. Hoyle), I have been able to examine and describe here.

SUMMARY OF PREVIOUS RECORDS.

Before describing the specimens which I have had an opportunity of examining, it may be well to give a sketch of the previous records of fossil plants from this coalfield. As far as possible the nomenclature has been revised in each case; the more recent names being placed on the right hand side of the original record. Where no emendation is given, the original name still holds good. The reasons for these changes in nomenclature will be found stated in the description of specimens, which follows.

The earliest account of plants from the Manchester Coalfield, with which I am acquainted, is that of the late Professor W. C. Williamson, for many years Professor of Natural History at Owens College, Manchester, whose researches on the structure of carboniferous plants rank as one of the most valuable contributions to Palæobotany during the past century. In 1836, Williamson[1] recorded the following species from the red shales, 60 feet above the Main or Three Yards Limestone, at Ardwick.

Calamites decoratus Brong.	=	*C. Suckowii* Brong.
Calamites nodosus	=	*C. ramosus* Art.
Lepidodendron Sternbergii	=	*L. lycopodioides* Sternb.
Neuropteris cordata	=	*N. Scheuchzeri* Hoffm.
Cyclopteris sp.	=	*Neuropteris* sp.
Stigmaria ficoides.		

[1] Williamson ('36), pp. 349—350.

Fragments of *Pecopteris* and *Asterophyllites** also occur in these beds. From the "blue clay above black bass" a *Sphenophyllum*, much like *S. erosum*, was found, and *Stigmaria ficoides* is noticed as occurring abundantly in the seam of coal below the black bass. *Equisetum*† is also recorded.

In 1839 Murchison[1], in his *Silurian System*, showed the close identity of the flora of the Manchester Coal-field with that of the coal measures near Shrewsbury, and mentions a "leaf of a large Monocotyledonous plant" from the latter coalfield, and that the same species occurs "particularly in the Upper Coal Measures at Ardwick." This plant is probably identical with that recorded by Salter, and by Binney as *Poacites*, which, as will be seen (p. 11), is an imperfect Calamitean pith-cast. Murchison also quotes a letter from Professor Phillips[2], who had studied the Ardwick Series, apparently independently of Williamson, and who gives a list of plants which is practically identical with the earlier record, with the addition of a "leaf of a Monocotyledonous plant"† and "very narrow Monocotyledonous leaves resembling *Noggerathia foliosa*."‡

The next mention of fossil plants from this coalfield is that in [3]Binney's *Sketch of the Geology of Manchester*, published in 1841. He records from the valley of the Medlock in a bed of bind above the Main Limestone,

Neuropteris cordata = *N. Scheuchzeri* Hoffm.

and most of the plants from Leebotwood and Uffington, in Shropshire[4]. The floors of the coals afford *Stigmaria ficoides*, *Calamites*, and other plants. Very fine specimens

* = *Annularia*. † = ? *Calamites*. ‡ = ? *Cordaites* sp.

[1] Murchison ('39), p. 85.
[2] Murchison *ibid.*, p. 88.
[3] Binney ('41)[1], pp. 50 and 58.
[4] *See* Murchison ('39), *ibid.*

of fossil Coniferous wood occur in the thick grit rock of Smedley in the valley of the Irk. In another paper[1], published in the same year, an account of the Pendleton Coalfield is given, and *Stigmaria ficoides* is recorded as very common in the horizon of the "Four feet Coal."

In an appendix to Hull's *Memoir on the Country round Bolton-le-Moors*, published in 1862, Salter[2] records *Lepidostrobus* sp. and *Lepidodendron* sp. from Patricroft.

In 1864 Salter[3] also gave a list of plants from Ardwick and Bradford, near Manchester, which is as follows :—

A.—ARDWICK SERIES AT ARDWICK.

Without horizons.

Sphenophyllum sp.
**Asterophyllites longifolia* = *Annularia stellata* Schl.

Above the 4-foot Mine.

Pecopteris Miltoni.
**Pecopteris abbreviata* = *Pecopteris Miltoni* (Art.)
Poacites sp. = *Calamites* sp.
Cyclopteris flabellata = *Neuropteris* sp.
Neuropteris cordata = *Neuropteris Scheuchzeri* Hoffm.
Sphenopteris latifolia = *Mariopteris latifolia* (Brong.)

Below the 4-foot Mine.

Calamites Suckowii.
Calamites cannæformis = *Calamites* sp.

Below the Bassey Mine.

Lepidodendron Sternbergii = *L. lycopodioides* Sternb.
Calamites decoratus = *C. Suckowii* Brong.

* These specimens were stated to be in Mr. Binney's Cabinet.

[1] Binney ('41)[3], p. 161.
[2] Salter ('62), p. 44.
[3] Salter ('64), p. 66.

B. BRADFORD SERIES AT BRADFORD.

Above the 4-foot Mine.

Sphenopteris obtusiloba.

Below the 4-foot Mine.

Neuropteris tenuifolia

Sphenophyllum sp.

Lepidodendron elegans = *L. lycopodioides* Sternb.

Lepidodendron Sternbergii = *L. lycopodioides* Sternb.

Sigillaria sp.

Above the Yard Mine.

Lepidodendron Sternbergii = *L. lycopodioides* Sternb.

Lepidodendron obovatum.

Neuropteris flexuosa.

Sigillaria elegans.

Lepidostrobus sp.

Below the Yard Mine.

Stigmaria ficoides.

Further additions to Salter's records were made by Binney ([1]) in 1868, who gave a very complete list. Most of these specimens are now in the Sedgwick Museum, Cambridge, and many of them are named in Binney's handwriting.

The following plants were stated to occur "in a bed of purple shale lying 60 feet above the Main Limestones."

Pecopteris abbreviata	= *P. Miltoni* (Art.)
Pecopteris Serlii	= *Alethopteris Serlii* (Brong.)
Odontopteris sp.	?
Dictyopteris sp.	?
Poacites sp.	= *Calamites* sp.
Cyclopteris flabellata	= *Neuropteris* sp.
Neuropteris cordata	= *Neuropteris Scheuchzeri* Hoffm.

[1] Binney ('68)[1], p. 42.

Sphenopteris irregularis	=? *Sphenopteris obtusiloba* Brong.
Sphenopteris coralloides	= *S.* (*Corynepteris*) *coralloides* (Gutb.)
Asterophyllites longifolia	= *Annularia stellata* (Schl.)
Aphyllostachys ?	= *Palæostachya* sp.
Calamites Suckowii	
Calamites cannæformis	= *C.* sp.
Sigillaria elegans	
Lepidodendron Sternbergii	= *L. lycopodioides* Sternb.
Lepidophyllum	
Trigonocarpon	
Lepidostrobus variabilis	
Lepidostrobus comosus	= *Lepidostrobus* sp.
Lepidostrobus ornatus	= *L. variabilis* L. & H.
Lycopodites sp.	= *Lepidodendron* sp.

The same author[1] also described and figured two specimens from the red shales of the Upper Coal Measures at Ardwick, near Manchester.

Asterophyllites longifolia L. *and* H. = *Annularia stellata* (Schl.)

Palæostachya sp.

I am not acquainted with any further records of plants since 1868, with the exception of fragments of a *Neuropteris*, recorded by Brockbank and De Rance[2] at a depth of 1,299 feet in the Clayton Vale boring, Openshaw, and of imperfect fragments of *Neuropteris* and *Pecopteris* found by Roeder[3] in the section at Slade Lane, Burnage.

Notes on Specimens.

In the notes on specimens which I have had an oppor-

[1] Binney ('68)[2], pp. 17 and 28. Pl. VI., Figs. 3-4 and 4*a*. See also ('67), p. 46.

[2] Brockbank and De Rance ('91), p. 348.

[3] Roeder ('92), p. 119.

tunity of examining, I have not thought it necessary to give the full synonymy. Such a synonymy will be found in most cases in Mr. Kidston's Catalogue of Palæozoic plants in the British Museum. Only a few of the more important references, and some of those in which the species are figured, are given here. All the specimens described are from the Ardwick series.

EQUISETALES.

Calamites Suckow, 1784.

Act. Acad. Theod. Palat. Vol. V., p. 355.

Calamites (*Eucalamites*) *ramosus*, Art. ?

(*a*) Sedgwick* Mus. Camb., Carb. Plant Coll., Nos. 596, 597, 738, 1124, etc.
(*b*) Manchester Museum, Owens College.

Calamites ramosus.

1828. Brongniart, *Hist. végét. foss.*, p. 127, Pl. XVII., Figs. 5-6.

1886. Kidston, *Cat. Palæoz. Plants Brit. Mus.*, p. 26.

1886-8. Zeiller, *Bassin houill. de Valenciennes*, p. 345, Pl. LV., Fig. 3, Pl. LVI., Fig. 3.

Calamites (*Eucalamites*) *ramosus.*

1884. Weiss, *Abhand. geol. Specialk. von Preuss.* Bd. V., Heft 2, p. 98, Pl. II., Fig. 3; Pl. V., Figs. 1-2; Pl. VI.; Pl. VII., Figs. 1-2; Pl. VIII., Figs. 1, 2, 4; Pl. IX., Figs. 1-2; Pl. X., Fig. 1; Pl. XX., Figs. 1-2.

Williamson records *Calamites nodosus*, which is now known to be identical with *Calamites ramosus*, from Ardwick. I think that all the specimens among the Binney Collection should be referred to this species, but

* See footnote, p. 4.

the preservation is not sufficiently good to warrant more than a somewhat doubtful reference to this type of pith cast. *Calamites decoratus* is identical with *C. Suckowi.* Salter and Binney have recorded *C. cannæformis* Schl., but this species is a most unsatisfactory one with no clearly defined scientific characters[1]. These determinations are therefore of little value.

NOTE ON *Poacites* sp.

Both Binney and Salter have recorded from Ardwick certain specimens under the name *Poacites*, probably on account of a certain similarity between their fossils and a figure of an imperfect plant, also from the Lancashire Coalfield, described by Lindley and Hutton in their Fossil Flora as *Poacites cocoina.*[2] The genus *Poacites* was originally founded by Brongniart for the reception of certain Tertiary grass-like remains, to which Lindley and Hutton's specimens presumably bore some resemblance. Their type specimen is now in the British Museum[3]; and I agree with Mr. Seward[4] who has suggested that it is simply a badly preserved portion of a Calamite with very long internodes. Some of Binney's specimens (Nos. 596 and 1124) bear a very striking resemblance to Lindley and Hutton's plant, and are certainly only badly preserved Calamitean pith casts. One of these consists of stems with long internodes, the ridges and grooves of which are very much worn, and the structural characters of the nodes almost entirely obliterated. This deformation seems to have arisen as the result of rock movements which have given rise to slickensides. Evidence of such thrust-planes

[1] Kidston ('91), p. 364.

[2] Vol. II., pl. CXLIIb.

[3] British Museum (Nat. Hist.), Geological Department, Registered Number, V. 4304.

[4] Seward ('98), p. 366.

is very common in the softer beds of many coalfields. There is therefore good reason to believe that the specimens which were looked upon by Salter and Binney and others as remains of Monocotyledonous plants are only badly preserved Calamitean casts.

Annularia Sternberg, 1820.

Versuch. Darstell. Flora der Vorwelt, I., fass. 2, p. 32.

Annularia stellata (Schl.).

(*a*) Sedgwick Mus. Camb., Carb. Plant Coll., Nos. 957 (figured), 714, and 738.

(*b*) Manchester Museum, Owens College.
Figured Binney, *Pal. Soc.* "*Observations Struct. Foss. Plants*," Part I., 1868, pp. 28-29, Pl. VI., Fig. 3.

Annularia stellata.

1886. Kidston, *Cat. Palæoz. Plants Brit. Mus.*, p. 45.

1886-8. Zeiller, *Bassin houill. de Valenciennes*, p. 398, Pl. LXI., Figs. 3-6.

1898. Seward, *Fossil Plants*, Vol. I., p. 338, Fig. 88.

Mr. Kidston[1] has already suggested from the evidence of Binney's figure that this plant should be referred to *Annularia stellata.* At any rate, it is not identical with Lindley and Hutton's *Asterophyllites longifolia*, as Binney thought, and does not even belong to the same genus, for the free leaf segments are all coherent basally into a sheath. This character forms one important distinction between the genera *Annularia* and *Calamocladus* (*Asterophyllites*).

The Ardwick specimens seem to me to agree in all essentials with the definition of this species given by Mr. Seward in his *Fossil Plants*,[2] where a full description

[1] Kidston ('92), Part II., p. 419.
[2] Seward ('98), p. 338.

of this type of Calamitean foliage will be found. Mr. Kidston, however, who has recently seen the portion of the specimen figured by Binney which is at Cambridge, thinks that there is some room for doubt about this specific determination, on account of the imperfection of the preservation.

Calamitean Leaf-sheath.

Sedgwick Mus. Camb., Carb. Plant Coll., Nos. 385 (figured), and 1125.

Figured, Seward, *Fossil Plants*, Vol. I., p. 260, Fig. 56.

The Ardwick specimen, which Mr. Seward has figured in the first volume of his *Fossil Plants*, is of interest, as showing a form of Calamitean leaf-sheath, which is probably not very common, and which differs in certain respects from other types of Calamitean foliage. In this specimen the sheath is comparatively long ($2\frac{1}{2}$ cm.), and apparently composed of many segments united together. The free leaves, of which only one is shown in this specimen, are very short (·8 cm.) and narrow. A specimen rather similar to this is figured in Dr. Scott's *Studies in Fossil Botany* (p. 35, Fig. 11), and Germar[1] has also figured others of the same type[2]. These specimens do not seem to agree very well with the characters of the genus *Annularia*, the great group of Calamitean leaves, in which the free segments are united into a collar at the base. In *Annularia* the leaf-sheath is usually very short, and the free leaves much longer than the sheath, while in this specimen they are almost reduced to teeth-like appendages. Also in *Annularia* the leaves are usually linear-lanceolate. Here, however, their general character rather recalls those of

[1] Germar. ('44), Fasc. 2, Pl. x., Figs. 2-3.

[2] The sheath in these specimens is larger, and the free segments very much smaller than in the fine examples of *A. stellata* figured by Potonié ('93), Figs. 1-2.

certain species of the recent *Equisetum*, in which the free segments are much reduced, and the sheath especially prominent. It may be that in certain species of *Calamites* a similarly reduced type of leaf-whorl is borne on certain branches. I merely wish to point out here that these particular forms of Calamitean foliage differ markedly from the commoner types of *Calamocladus* and *Annularia*.

Palæostachya Weiss, 1876.
Steinkohl. Calamitien (1) p. 103 ; (2) p. 161.

Palæostachya sp.

(*a*) Sedgwick Mus. Camb., Carb. Plant Coll., No. 1127 (figured).

(*b*) Manchester Museum, Owens College.
Figured, Binney, *Observ. Struct. Foss. Plants*, Part I. (Pal. Soc.), 1868, Pl. VI., Fig. 4.

Mr. Kidston,[1] on the evidence of Binney's figure, referred this plant to *Palæostachya pedunculata* Will. in 1891. I have, however, recently shown him the actual specimen, which he thinks is too imperfect for specific determination. We are both agreed however that the cones belong to the genus *Palæostachya*, and are possibly, but not certainly, *P. pedunculata* Will. The interest in this specimen lies in the fact that the foliage of the cone-bearing branches, although too imperfect for determination, rather recalls the type of foliage just described as *Annularia stellata*, whereas the fructification belonging to that foliage is known to be *Stachannularia tuberculata* Sternb[2]. It is possible that there may be other types of foliage closely resembling *A. stellata*, which are very difficult or impossible to distinguish from it when preserved as impressions.

[1] Kidston (**'91**), p. 418.
[2] See Kidston ('94), p. 584.

SPHENOPHYLLALES.

Sphenophyllum Brongniart, 1822.

Sur la Class. Végét. foss., p. 34.

Sphenophyllum sp.

Sedgwick Mus. Camb., Carb. Plant Coll., Nos. 599 and 146.

The few specimens of *Sphenophyllum* among Binney's plants consist of stems without any leaves. The species cannot therefore be determined. One of these stems is seen in Fig. 4, of Plate I., in association with *Pecopteris Miltoni.*

CYCADOFILICES?

Neuropteris Brongniart, 1822.

Sur la Class. Végét. foss., p. 33.

Neuropteris Scheuchzeri Hoffm. Plate I., Fig. 3.

(*a*) Sedgwick Mus. Camb., Carb. Plant Coll., Nos. 634 and 956.

(*b*) Manchester Museum, Owens College.

Neuropteris Scheuchzeri.

1886. Kidston, *Cat. Palæoz. Plants Brit. Mus.*, p. 95.

1886-8. Zeiller, *Bassin houill. de Valenciennes*, p. 251. Pl. XLI., Figs. 1-3.

1888. Kidston, *Trans. R. Soc. Edinb.*, Vol. XXXIII. Pt. 2. p. 356. Pl. XXIII., Figs. 1-2.

1899. Zeiller, *Mém. Soc. géol. France, Paléont.* T. VIII. *Mém.* No. 21, Vol. IV. p. 43. Pl. IV., Fig. 9.

1903. Arber, *Q.J.G.S.*, Vol. LIX. p. 9. Pl. I., Fig. 1.

The plants referred by Williamson, Binney, and Salter to Brongniart's species *N. cordata*, are undoubtedly referable to *N. Scheuchzeri* Hoffmann. Brongniart's plant has, so far as I am aware, never yet been obtained from

British rocks. One point of distinction between these two species is the presence of characteristic marks on the frond of the latter, which are regarded as derived from bristle-like hairs which grew on the surface of the frond. These are rarely absent except where the preservation is very imperfect. In the specimen figured on Plate I., Fig. 3, the scratch-like markings on the frond are plainly seen. Mr. Kidston[1] has published the results of a critical examination of this species in his memoir on the Somerset Coalfield. This species is perhaps the most common fern-like plant in the Ardwick Series.

NOTE ON *Cyclopteris*, *Odontopteris*, *Dictyopteris*, &c.

Williamson and Binney record *Cyclopteris* sp. from Ardwick; and Salter, *Cyclopteris flabellata* from the same locality. I have not seen any of these specimens, but I may point out that *Cyclopteris* is no longer usually regarded as a true genus. It is now known that Cyclopteroid pinnules were borne on the rachis of several different species of *Neuropteris*[2].

The genera *Odontopteris* and *Linopteris (Dictyopteris)* recorded by Binney from Ardwick are somewhat doubtful determinations. They are both rare in Britain, and it is possible that they may have been recorded from specimens of *Neuropteris* by mistake. There is no trace of such plants among the Binney collection.

On the other hand, *Neuropteris tenuifolia* (Schl.), and *N. flexuosa* (Brongt.), recorded from Bradford by Salter, are very possibly correct determinations. Here, again, I have not seen any specimens of these species.

Sphenopteris (Corynepteris) coralloides (Gutb.), recorded

[1] Kidston ('88), p. 356.
[2] *See* Zeiller ('00), Fig. 80, p. 106.

from Ardwick by Binney, is also a somewhat doubtful identification. It is a comparatively rare British plant.

2. *Neuropteris gigantea* (Sternb.)?

Sedgwick Mus. Camb., Carbon. Plant Coll., No. 1124.

Neuropteris gigantea.

1828. Brongniart, *Hist. Végét. foss.*, p. 240, Pl. LXIX.
1886. Kidston, *Cat. Palæoz. Plants, Brit. Mus.*, p. 92.
1886-8. Zeiller, *Bassin houill. de Valenciennes*, p. 258, Pl. XLII., Fig. 1.
1900. Zeiller, *Elém de Paléobot.*, p. 105, Fig. 79.
1901. Kidston, *Proc. York Geol. and Polyt. Soc.*, Vol. XIV., p. 193, Pl. XXVIII., Fig. 3, and Pl. XXIX., Fig. 4.

FILICALES.

Pecopteris Brongniart, 1822.

Sur la Class. Végét. foss., p. 33.

Pecopteris Miltoni (Art.), Plate I., Fig. 4.

Sedgwick Mus. Camb., Carbon. Plant Coll., Nos. 596-599.

Pecopteris Miltoni.

1828. Brongniart, *Hist. Végét. foss.*, p. 333, Pl. CXIV.
1886. Kidston, *Cat. Palæoz. Plants Brit. Mus.*, p. 120.
1888. Kidston, *Trans. R. Soc. Edinb.*, Vol. XXXIII., p. 374.

Pecopteris abbreviata.

1828. Brongniart, *Hist. Végét. foss.*, p. 337, Pl. CXV., Figs. 1-4.
1831-7. Lindley and Hutton, *Foss. Flora*, Pl. CLXXXIV.
1886-8. Zeiller, *Bassin houill. de Valenciennes*, p. 185, Pl. XXIV., Figs. 1-4.

Pecopteris Miltoni, like many other Carboniferous ferns, is a very variable species, and there has been much difference of opinion as to whether *P. abbreviata* Brong. should be regarded as a species distinct from *P. Miltoni* (Artis). It is, however, believed that no good characters exist for separating these plants. A discussion on this subject will be found in Mr. Kidston's memoir[1] on the Fossil Flora of the Somerset Coalfield. *P. Miltoni* is a very abundant and characteristic plant in the Ardwick Series. A frond of this species is figured on Plate I., Fig. 4.

Mariopteris Zeiller 1879.

Bull. Soc. géol. France. Sér. 3, Vol. VII., p. 92.

Mariopteris muricata (Schl.)?

Sedgwick Mus. Camb., Carb. Plant Coll., No. 385 and 599.

Mariopteris muricata.

1886. Kidston, *Cat. Palæoz. Plants Brit. Mus.*, p. 109.

1886-8. Zeiller, *Bassin houill. de Valenciennes*, p. 173, Pl. XX., Pl. XXI., Pl. XXII., Figs. 1-2; Pl. XXIII

Pecopteris muricata.

1828. Brongniart, *Hist. Végét. foss.*, p. 352, Pl. XCV., Figs. 3-4; Pl. XCVII.

Mariopteris muricata is one of the commonest of Coal-measure plants, and occurs in all divisions of the Upper Carboniferous, though less abundantly in the Upper Coal Measures.

LYCOPODIALES.

Lepidodendron Sternberg 1820.

Versuch. Darstell. Flora der Vorwelt, I., fass. 1, p. 23.

1. *Lepidodendron lycopodioides* Sternb.

Sedgwick Mus. Camb., Carb. Plant Coll., No. 1123, 958, 599.

[1] Kidston ('88), p. 374.

Lepidodendron lycopodioides.

1886-8. Zeiller, *Bassin houill. de Valenciennes*, p. 464., Pl. LXIX., Figs. 2-3, and Pl. LXX., Fig. 1.

1893. Kidston, *Geol. Trans. Yorks. Nat. Union.* "Carb. Flora of Yorkshire, 4th Report," p. 109.

Lepidodendron elegans.

1828 Brongniart, *Hist. Végét. foss.*, Vol. II., p. 35, Pl. XIV.

1831-7. Lindley and Hutton, *Foss. Flora*, Vol. II., Pl. CXVIII.

TEXT FIGURE.

Lepidodendron lycopodioides Sternb., from the Ardwick Series, Manchester (Sedgwick Museum, Camb., No. 1,123.) Nat. Size.

This species of Lepidodendron, formerly known as *L. Sternbergii*,[1] is the most common Lycopod in the

[1] Kidston ('86), p. 148, and 1893 (mentioned above), p 109.

Ardwick Series. In association with fairly well-preserved stems showing the characteristic leaf bases, numerous young shoots occur, which are densely clothed with leaves. These leafy branches are the plants recorded by Binney as *Lycopodites* sp. One of the specimens from Ardwick is thus labelled in Binney's hand-writing. Similar specimens from Ardwick are in the Manchester Museum, Owens College.

2. *Lepidodendron dichotomum* Zeiller (? Sternb.)

Sedgwick Mus. Camb., Carb. Plant Coll., No. 959. Plate I., Figs. 1 and 2.

Lepidodendron dichotomum.

1886-8. Zeiller, *Bassin houill. de Valenciennes*, p. 446, Pl. LXVII., Fig. 1.

? 1820-38. Sternberg, *Versuch. geog. bot. Darstell. Flora der Vorwelt* I., fass. I., pp. 19 and 23, Pl. I. and II.; fass. II., p. 177, Pl. LXVIII., Fig. 1.

? *Lepidodendron Peachii.*

1885. Kidston, *Ann. and Mag. Nat. Hist.*, Vol. XV., Ser. V., p. 363, Pl. XI., Fig. 6.

1885. Kidston, *Proc. R. Phys. Soc. Edinb.*, Vol. VIII., p. 421, Pl. XXI., Fig. 6.

This species is a very interesting one, and one which is comparatively rare in British rocks. The Ardwick specimen is regarded by Mr. Kidston, to whom I have referred it, as identical with the plant figured by Zeiller as *L. dichotomum.* Mr. Kidston is not at present quite convinced that Zeiller's plant is identical with that first described by Sternberg under the same specific name. The Ardwick species may also be identical with some specimens described in 1885 by Mr. Kidston as *L. Peachii*, from Falkirk, Stirlingshire, and from the Middle Coal

Measures of Newsham, Newcastle-on-Tyne. In 1896, further specimens were obtained from the Lower Coal Measures of Southowram, near Halifax, in Yorkshire. There is still, however, some little uncertainty whether *L. Peachii* is identical with *L. dichotomum.*

Part of the specimen is figured on Plate I., Fig. 1. A magnified portion of another stem occurring on the same specimen is also shown in Fig. 2. The latter shows the characters of the leaf cushions very clearly. The leaf cushion is about 4 mm. long, and nearly as broad as long. The leaf scar is close to the upper margin of the leaf cushion, and is transversely elongate. The keel is not very well marked, and the glandular pits in the *field* below the leaf scar are apparently absent in this specimen. This may, however, be possibly accounted for by indifferent preservation.

Lepidophyllum Brongniart 1828.

Prod. Hist. Végét. foss., p. 87.

Lepidophyllum sp.

Sedgwick Mus. Camb., Carb. Plant. Coll., No. 956.

Lepidostrobus Brongniart 1828.

Prod. Hist. Végét. foss., p. 87.

Lepidostrobus variabilis L. and H.

Sedgwick Mus. Camb., Carb. Plant Coll., Nos. 146 and 1,126.

Lepidostrobus variabilis.

1831-7. Lindley and Hutton, *Fossil Flora,* Vol. I., Pl. XXXI.

1886. Kidston, *Cat. Palæoz. Plants Brit. Mus.*, p. 197.

This species of Lepidodendroid fructification is an unsatisfactory one, including cones of a certain type whose preservation will not permit of a more exact determination. It is fairly abundant in the shales of the Ardwick Series. *Lepidostrobus ornatus* is now known to be identical with this species. I do not believe, however, that any specimens of *L. comosus*, a Lower Carboniferous type of cone, were ever obtained from the Ardwick Series, although recorded by Binney.

Stigmaria ficoides (Sternb.)

I have not seen any specimens of *Stigmaria* from the Ardwick Series. There is, however, a fine specimen from Bradford, Manchester, in the Owens College Museum.

THE PALÆOBOTANICAL EVIDENCE OF THE HORIZON OF THE ARDWICK SERIES.

The previous opinions which have been expressed with regard to the position of the Ardwick Series in the Carboniferous System are practically unanimous. Murchison,[1] Binney,[2] Hull,[3] and others[4] have assigned them to the Upper Coal Measures. It is also commonly stated in the text-books that the Ardwick Series occupies the highest position in the Coal Measures of this country. The evidence of the fossil plants supports this conclusion in so far as by the term "Upper Coal Measures" is implied a horizon higher than the Middle Coal Measures. They, however, afford still further evidence. The Ardwick Series belongs to a horizon immediately above the Middle Coal Measures, which is regarded, on palæobotanical grounds, as distinct from the true Upper Coal Measures.

[1] Murchison ('39), p. 85.
[2] Binney ('68)[1], &c.
[3] Hull ('62), ('64), and ('81).
[4] Roeder ('92), and others, *see* Bibliography.

In other words, a horizon is now recognised, which is intermediate between the true Upper and the Middle Coal Measures. This is known as the Upper Transition Series. The general character of the flora of this horizon is a mixture of Upper and Middle Coal Measure types. This transitional series has now been recognised in several coalfields. The Lower Pennant Grits of South Wales[1], the New Rock and Vobster Series in the Somersetshire Coalfield[2], and certain beds in the Potteries Coalfield[3], belong to the Upper Transition Series. The Ardwick Series is the equivalent of these beds. The true Upper Coal Measures, to which belong the Upper Pennant Series of South Wales, the Radstock and Farrington Series in the Somersetshire Coalfield, and the workable coals of the Forest of Dean Coalfield, are not represented in the Manchester or the South Lancashire Coalfields.

The species, which have been described here from Ardwick, and others which have previously been recorded from the Ardwick and Bradford Series, are as follows:—

Ardwick Series.

List of Species in the Binney Collection at Cambridge.

Calamites (*Eucalamites*) *ramosus* (Art.)?
Annularia stellata (Schl.)
Palæostachya sp.
Sphenophyllum sp.
Neuropteris Scheuchzeri, Hoffm.
Neuropteris gigantea Sternb.?
Pecopteris Miltoni (Art.)
Mariopteris muricata (Schl.)?
Lepidodendron lycopodioides Sternb.

[1] Kidston ('94), pp. 573—4.
[2] Kidston ('88).
[3] Kidston ('97), p. 129.

Lepidodendron dichotomum, Zeill. = ? Sternb.
Lepidophyllum sp.
Lepidostrobus variabilis L. and H.

ADDITIONAL RECORDS BY PREVIOUS WRITERS.

Calamites (*Stylocalamites*) *Suckowi* Brong.
Alethopteris Serli (Brong.)
? *Sphenopteris obtusiloba* Brong.
Mariopteris latifolia (Brong.)
Sigillaria elegans Brong.
Stigmaria ficoides (Sternb.)
Trigonocarpus sp.

BRADFORD SERIES.

(600 feet below the Ardwick Series.)

SALTER'S RECORDS.

Sphenophyllum sp.
Sphenopteris obtusiloba Brong.
Neuropteris flexuosa Brong.
Neuropteris tenuifolia (Schl.)
Lepidodendron obovatum Sternb.
Lepidodendron lycopodioides Sternb.
Sigillaria elegans Brong.
Sigillaria sp.
Lepidostrobus sp.
Stigmaria ficoides Sternb.

Of the ten species from the Ardwick Series which are here described, seven occur in the Middle, and seven in

[1] The following previous determinations are doubtful: *Odontopteris* sp., *Sphenopteris* (*Corynepteris*) *coralloides* (Gutb.). The following records are rejected: *Poacites* sp., *Calamites cannæformis* Schl., *Cyclopteris flabellata*, *Linopteris* (*Dictyopteris*) sp., *Lepidostrobus comosus* L. H., *Lycopodites* sp.

the Upper Coal Measures. There are, however, two species, *Annularia stellata* (Schl.), and *Lepidodendron dichotomum* Zeiller (? Sternb.), which are confined to the Upper Coal Measures or to the Upper Transition Measures; and two others, *Neuropteris Scheuchzeri* Hoffm., and *Alethopteris Serli* (Brong.), the latter recorded by Binney, which are very much more abundant in the Upper than in Middle or Lower Coal Measures. The occurrence of these species distinguishes the Ardwick flora from that of the Middle Coal Measures. On the other hand, the number of Middle Coal Measure plants present in these beds, and the absence of many typical Upper Coal Measure species, *e.g.*, *Pecopteris arborescens* (Schl.), show that we are not dealing here with a flora belonging to the true Upper Coal Measures.

The fossil flora of the Bradford Series, more than 600 feet below the Ardwick beds, differs rather remarkably from that of the higher horizon. I have not seen any of the specimens which Salter has recorded, but if his determinations are correct, these beds probably also form part of the Upper Transition Measures of the Lancashire Coalfield. Most of the species mentioned in the above list do not extend above the Middle Coal Measures. But *Neuropteris tenuifolia* (Schl.) occurs in the Upper Transition Series of the South Wales Coalfield, and *Neuropteris flexuosa* Brong. is confined to the Upper and the Upper Transition Coal Measures. The evidence for the position of the Bradford Series is not, however, so satisfactory as that of the Ardwick beds.

The occurrence of an Upper Transition flora in association with beds of "*Spirorbis* Limestone" is worthy of further remark, for, in the Manchester Coalfield, these limestones are better developed than in any other British area. Such an association has also been found to occur in certain other coalfields, *e.g.*, the Potteries Coal-field[1]. "*Spirorbis* Limestones" overlie beds of Middle Coal Measure age in the Cumberland Coalfield, and although very few, if any, plants have yet been obtained from the Upper Division of the Sandstone Series of Whitehaven, it is possible that this division is also the equivalent of the Upper Transition Series in other coal-fields[2]. On the other hand, while it has been shown on palæobotanical evidence that the horizon on which the *Spirorbis* Limestones occur in certain coalfields is constant, yet it has also been recently pointed out that this is not always the case. In the Upper Carboniferous rocks of North Staffordshire, Mr. Walcot Gibson[3] has shown that these limestones have a wide vertical distribution. Their occurrence is therefore not to be relied upon as marking any particular horizon in the Carboniferous rocks, as was formerly supposed, and the true position of such limestone bands can only be ascertained by an examination of the flora of the associated beds. The use of the term "Ardwick Stage" as a horizon of wide occurrence in British coalfields is misleading if founded on a particular lithological type, whereas, so far as our knowledge extends, it is widely applicable as a palæobotanical subdivision of the Coal Measures.

[1] Kidston ('97).
[2] Arber ('03), p. 17.
[3] Gibson ('01).

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EXPLANATION OF THE PLATE.

All the specimens are from the Ardwick Series, and are now in the Sedgwick Museum, Cambridge.

(Photographs by Mr. Tams, Cambridge.)

Plate I.

Fig. 1. *Lepidodendron dichotomum*, Zeiller (? Sternb.), No. 959. Very slightly enlarged.

Fig. 2. *Lepidodendron dichotomum.* Portions of another stem included in the same specimen, and part of Fig. 1, $\times 2\frac{1}{2}$.

Fig. 3. *Neuropteris Scheuchzeri*, Hoffm. No. 634. Very slightly enlarged.

Fig. 4. *Pecopteris Miltoni* (Artis). No. 599. Very slightly enlarged.

FIG. 1.

FIG. 2.

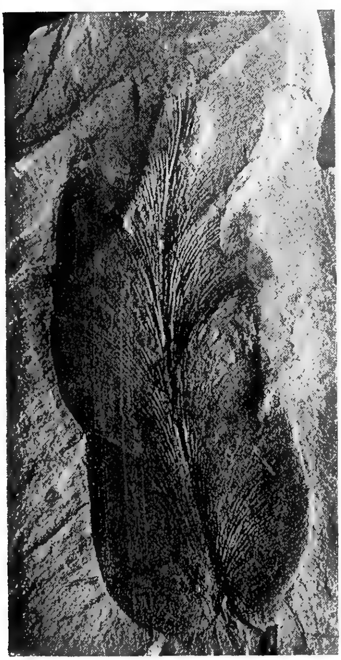

FIG. 3.

FIG. 4.

Manchester Memoirs, Vol. xlviii. (1903), *No.* **3**.

III. On a Method of Ice Calorimetry.*

By H. E. SCHMITZ, M.A., B.Sc.

Read November 3rd. Received December 1st, 1903.

Introductory.

If a body at a temperature below 0°C. is plunged into water at 0°C. a coating of ice forms round the body. The mass of the ice is a measure of the quantity of heat absorbed by the body when its temperature rises to 0°C. If it is required to determine the specific heat of the material of which the body is composed, we may apply the following equation :

$$\text{Specific heat} = \frac{\text{Mass of ice} \times \text{Latent heat of water}}{\text{Mass of body} \times \text{Initial temperature of body}}$$

This method of calorimetry possesses the great advantage of simplicity of principle. This advantage it shares with the method of steam calorimetry so successfully used by Joly, and also with the converse method of ice calorimetry practised by Black, Wilke and Lavoisier and Laplace, but abandoned by later workers.†

We may attempt to determine the mass of ice formed round the cold body in either of two ways. The ice-coated body may be weighed while suspended in the water of the calorimeter, or it may be removed from the water and then weighed. In the first case it is necessary to know the density of the ice formed, and the inclusion of air-bubbles will be fatal to the success of the method. In the second case it is essential that *water* shall not be included within the ice-coating, and water must not be

* This paper contains a more complete account of experiments of which a summary is given in the *Proceedings* of the Royal Society, Vol. 72, pp. 187-190.

† Bunsen's well-known method hardly belongs to the class of methods here considered.

December 30th, 1903.

allowed to remain adhering to the external surface of the ice-coating.

Professor Joly, in a letter to *Nature*,* gave the principle of a gravimetric ice calorimeter in which an object suspended from one arm of a balance is first cooled below 0°C. and then immersed in ice-cold water. Professor Joly kindly allows me to publish the following additional details. The object under experiment is almost completely enclosed within a copper sphere. This sphere is the inner of two concentric spheres, between which the refrigerating material circulates. Outside the outer sphere is a space for water and ice, poured in at the last moment. The spheres are made up of two separate hemispherical portions; these close on a vertical diametral plane and are held closed, watertight, by screws. A hole through one of the hemispherical portions admits a mercury or platinum thermometer. After the temperature of the substance has become constant, a plug at the base of the pair of spheres is withdrawn and water at 0°C. flows up around the substance from the outer space. An ice-jacket is thus formed upon the object. The weighing is made while the object, with its ice-jacket, remains suspended in the ice-cold water.

Messrs. Bedford & Green, in a communication to the British Association of 1901,† gave a preliminary account of a method in which the object under experiment is first placed in a cold chamber for a sufficient time, then carried to a calorimeter containing ice-cold water, and, with its ice-jacket, weighed during immersion.

Professor Dewar has described ‡ a similar method, but has not published details.

* Vol. 52, p. 80, 1895.
† Report, p. 544.
‡ British Association, 1903.

In my own experiments I used the method of weighing in air. It was in fact useless to hope for any reliable result by weighing in water, for the object was cooled by direct immersion in liquid air and necessarily carried a certain quantity of liquid air into the calorimeter, where a larger or smaller quantity was vaporised *within the ice-coating.*

My method of procedure was briefly as follows.

A piece of metal, generally a cylinder with rounded ends, was immersed in liquid air for a time sufficiently long for the establishment of equilibrium of temperature. It was withdrawn by means of a silk thread passing through a hole in a small projection at one end of the axis of the cylinder, and was carried to a calorimeter containing ice-cold water, the transference lasting five seconds or less, and the greater part of the adhering liquid air being shaken off during the transference. It was allowed to remain suspended in the calorimeter for a sufficient time, then, with its ice-coating, was removed to a vessel in which the surface of the ice was dried by contact with ice-cold filter paper, and was finally placed in another vessel and weighed.

The Method of Cooling the Object.

The piece of metal was cooled by direct immersion in the liquid air. This procedure has the great advantage that we can be practically certain that the metal, if it has remained in the bath of liquid air for a sufficient time, is, at the moment of extraction, at the same temperature as the liquid air. It has the disadvantage that liquid air adheres to the surface of the metal and is carried over into the calorimeter. As will appear more fully in the sequel, the liquid air carried over, however small in amount, causes trouble, not from any direct calorimetrical effect, but from the fact that it prevents the formation of an ice-coating completely enclosing the piece of metal. The direct calorimetrical effect is exceedingly small: in fact, if we attempt to make it large by allowing the object to carry a comparatively large amount of liquid air into the calorimeter, we find that the bulk of the liquid air immediately rises to the surface of the water, where it sometimes forms its own independent ice-capsules before evaporating.

As regards the time necessary to cool the object to the temperature of the liquid air, this is easily settled, either by observing the behaviour of the liquid air or by quantitative experiments. The necessary time, in the case of the objects I used, was five minutes or less, but my practice was to allow the object to remain in the bath of liquid air for a quarter of an hour or longer.

In a few experiments I cooled the piece of metal by allowing it to remain for a long time in a corked test-tube immersed to a considerable depth in liquid air. On plunging the cold metal into the calorimeter, an ice-jacket was formed completely enclosing the piece of metal, of very uniform thickness when the piece of metal was spherical, and in some other respects superior to the ice-jacket formed in my usual method of procedure. I made however few quantitative experiments using this method of cooling, for the following reasons. It seemed doubtful whether even a prolonged cooling would reduce the metal to the temperature of the liquid air.* The temperature

* A platinum thermometer, protected by a corked glass tube with a metal base from direct contact with the liquid air, showed a temperature far from steady and differing by several degrees from the temperature of the liquid air, during observations continued for ninety minutes. But in this case it is probable that the thick wire terminals had an appreciable effect in keeping up the temperature of the coil.

of liquid air changes at a rate which is considerable in the case of a small quantity, and it seemed very unlikely that the fluctuations of temperature of the metal would follow those of the liquid air at all closely. Lastly, the rise of temperature of a cold dry body during the transference to the calorimeter is considerably greater than that of a body wet with liquid air.

I shall not again refer to the method of cooling by protected immersion, but I should like to suggest that this method would probably repay investigation if liquid oxygen or a large supply of liquid air were available.

The Transference from Cooler to Calorimeter.

In a series of experiments by the method of mixtures on the heating of a copper cylinder during its transference from a bath of liquid air to a calorimeter, I found that the rise of temperature per second was less than ·001 of the whole temperature difference. From these experiments and from observations on other specimens, I concluded that, for a transference lasting not more than five seconds, the heating effect of the atmosphere might be neglected, being approximately neutralised by the calorimetric effect of the small amount of liquid air still adhering to the object at the moment of immersion.*

In the present method the adhering liquid air has practically no effect on the weight of ice formed, that is, it has no compensating calorimetric effect. I found it convenient, however, to use a time of transference of three or five seconds; various errors, which will be considered later, made it superfluous to apply any correction for heating during transference.

The following numbers, the results of some early experiments by the present method, illustrate the effect

* *Proc. Roy. Soc.*, vol. 72, pp. 180—186.

of an alteration in the time of transference. They were given by a flat-ended copper cylinder, weighing a little over 100 grammes, suspended with its axis vertical, and carried steadily from cooler to calorimeter. It may be remarked that the time required for complete evaporation of the liquid air from the surface of the cylinder was 15 to 20 seconds.

Time of transference in seconds.	Apparent specific heat.
5	·0796
10	·0792
15	·0800
20	·0772
25	·0774
30	·0773
60	·0743

Subsequent experience showed that the shape of the object here used was not well adapted for obtaining consistent results by the present method; but the numbers above given are sufficient to show that any heating which may occur in five seconds is not of much importance.*

* Five experiments with the same cylinder, in which the transference was made as rapidly as possible, gave respectively ·0793, ·0799, ·0787, ·0805, ·0806, mean ·0798. A small copper cover was made, closely fitting over the curved surface and base of the cylinder, and provided with a hook below so that it could be rapidly withdrawn by means of an attached thread. In three

The Calorimeter.

The calorimeter was of very simple construction, and is shown in section in Fig. 1. It consisted of three coaxal metal cylinders, the innermost containing water, the other two ice and water (to the levels indicated in the diagram). For better insulation the whole arrangement was supported at a few points within a wooden box. The water in the innermost vessel was frequently stirred (stirrer omitted in the diagram). A wire-gauze tray (not shown in the

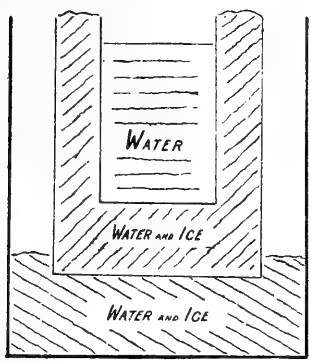

FIG. 1.

diagram), hanging from the rim of the containing vessel, dipped below the surface of the water; this contained ice. This tray was removed for the insertion of the cold object in the calorimeter, but was replaced as soon as possible; it was so constructed as not to interfere with the suspension of the object. It was unfortunately

experiments the cylinder was cooled in the liquid air with its curved surface and base protected in this manner from contact with the liquid air; the cover was rapidly withdrawn immediately on removing the cylinder from the liquid air; these experiments gave respectively ·0799, ·0797, ·0802, mean ·0799, or practically the same number as when the cover was not used. These results show that the amount of adhering liquid air (small in the last three experiments, relatively large in the first five) may be considerably varied without much influencing the result.

not used in the earlier experiments, but was found to be a distinct improvement.

The average temperature of the water in the calorimeter was slightly above 0°C. When the tray of ice was used the thermometer gave a reading of 0·01° to 0·05°. When it was not used the temperature was slightly higher, but probably not often above 0·1°. The fact that the temperature is not zero makes the initial weight of ice slightly too small (say by one part in one thousand in extreme cases), and further diminishes it by a gradual melting. The correction for initial deficiency was too small to take account of. The correction for gradual melting was also too small to take account of; this is shown by the following experiments. (1) A piece of ice of mass 14 grammes was weighted with a bullet and weighed on a sensitive balance while immersed in the calorimeter, the ice-tray not being used; the rate of melting was 4 per cent. per hour. (2) A piece of ice of mass $5\frac{1}{2}$ grammes was similarly weighed, the ice-tray being in position; there was no appreciable melting in one hour.

The Drying Apparatus.

In my earlier experiments I dried the ice-jacket by the application of filter-paper cooled by means of melting ice. As it was desirable to make the drying process as mechanical as possible, I ultimately adopted the form of apparatus shown diagrammatically in Fig. 2.

A deep cylindrical metal vessel A is firmly supported (supports omitted in the diagram) within an earthenware jar containing ice and water. A second metal vessel B, of the shape indicated in the figure, fits loosely in A, and contains ice. The lower part of the vessel A contains filter-paper suitably arranged for the purpose of drying the particular specimen. My practice was to remove the cover B, insert the specimen as quickly as possible after shaking off the bulk of the adhering water, adjust the filter-paper over the top of the specimen (using for this purpose cooled crucible tongs), and finally to replace and press down the cover B.

In most experiments I allowed the object to remain in the dryer for half a minute. In two control experiments the object was allowed to remain in the dryer for ten

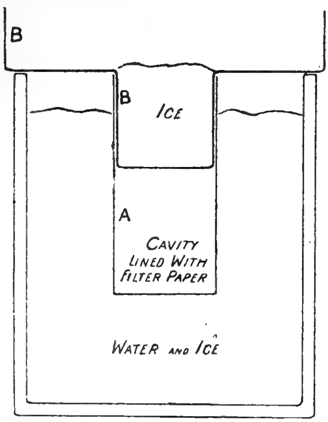

FIG. 2.

minutes ; contrary to expectation, the results in both cases gave a slight excess ($\frac{1}{2}$ per cent.) for the weight of ice (or ice and water); this may have been due to the use of damp filter-paper.*

The Weighing.

After removing the ice-coated object from the drying apparatus, I placed it in a metal vessel and weighed it as quickly as possible. The deposition of dew on the metal

* The actual numbers, representing the apparent specific heat of copper, were in these two experiments 0·0797 and 0·0796. Two similar experiments in which the same piece of copper (a cylinder weighing 161$\frac{1}{2}$ grammes) remained in the dryer for half a minute gave 0·07945 and 0·0792.

vessel and on the balance-pan produced in some cases a small error; I found that this might amount to a few centigrammes in a protracted weighing, but it was easily reduced to one or two centigrammes by arranging beforehand for a quick weighing. The error due to convection currents was found by experiment to be very small.

I have not applied any correction for the weight of air displaced by the ice. Such a correction (one part in one thousand) would be rather greater than the correction for deposition of dew in my experiments and of opposite sign; for the present purpose the two corrections may be taken as neutralising one another.

Temperature of the Liquid Air.

To determine the temperature of the liquid air I made a platinum thermometer with exposed coil. My thanks are due to Mr. J. E. Petavel for information as to details of construction. The readings were taken with an Elliott box (previously standardised) and a single Leclanché cell. The resistances at 0°C. and 100°C. were determined with great care, and with various modifications of method. In the absence of a supply of liquid oxygen the resistance at − 182·5°C. (taken as the temperature of liquid oxygen) was determined by placing the instrument in a narrow test-tube from which the last remainder of a quantity of liquid air was allowed to evaporate; the steady resistances obtained in a number of independent experiments by this method agreed very closely. δ (of Callendar's well-known formula) was found to be 2·47 (the last figure of doubtful significance). This value may be compared with the following numbers given by Professor Dewar* for two platinum thermometers:—2·5797, 2·6767. The wire was of pure metal, 36 S.W.G., obtained from Messrs. Johnson, Matthey, & Co.

* *Proc. Roy. Soc.*, Vol. 68, p. 363, 1901.

The lowest temperature of the liquid air in my observations was − 191·0°C. My practice was to observe the temperature half a minute or a quarter of a minute before the extraction of the piece of metal.

The temperature of the piece of metal some seconds after its extraction from the bath of liquid air is of course not precisely that of the liquid air, but, as already stated, I do not think that the difference is at all an important one.

Consistency of Results.

The results shown in the following tables were obtained after many preliminary experiments of various kinds with pieces of metal of various shapes and sizes. Each table gives all the experiments made with the piece of metal in question. These experiments (except the last two on aluminium) were made without using the ice-tray described on page 7. The transference to the calorimeter was effected as rapidly as possible (except again in the case of the last two experiments on aluminium).

TABLE I.

Cast-iron ball, surface moderately rough, mass 110·55 grammes, iron hook for suspension.

Time in calorimeter (in minutes).	Initial emperature.	Mass of ice (in grammes).	Apparent specific heat.
7	− 183·4	22·50	·0888
7	− 183·8	22·53	·0887
5	− 186·0	22·72	·0884

TABLE II.

Zinc ball, surface smooth, mass 106·55 grammes, brass hook for suspension.

Time in calorimeter (in minutes.)	Initial temperature.	Mass of ice (in grammes).	Apparent specific heat.
5	– 185·8	20·74	·0838
5	– 182·6	20·39	·0838
5	– 190·0	21·26	·0840
5	– 186·4	20·85	·0840
5	– 184·6	20·56	·0836

TABLE III.

Tin plummet, surface pitted with blow-holes, mass 129·70 grammes, ring of very fine copper wire for suspension.

Time in calorimeter (in minutes).	Initial temperature.	Mass of ice (in grammes).	Apparent specific heat.
5	– 189·8	15·48	·0503
5	– 188·0	15·41	·0506
5	– 189·8	15·57	·0506

TABLE IV.

Aluminium cylinder with hemispherical ends, surface fairly smooth, mass approximately 104 grammes, small projection at one end of axis for suspension.

Time in calorimeter (in minutes).	Initial temperature.	Mass of ice (in grammes.)	Apparent specific heat.
20	– 186·8	37·25	·154
7	– 189·7	37·32	·1515
7	– 189·4	37·18	·151
5	– 184·0 ?	36·78	·154 ?
5	– 188·0	37·15	·152
5	– 187·3	37·36	·154

The least consistent of these observations are those for the aluminium cylinder. This cylinder, for some reason not obvious, but perhaps simply on account of its comparatively large surface, carried an unusually large amount of liquid air into the calorimeter, and to this circumstance I attribute the want of agreement in the results shown in Table IV.

The results shown in these tables agree very nearly with results obtained by the method of mixtures for the same specimens. The method of mixtures gave (for the slightly different range – 185°C to + 15°C.) the following numbers :—

·089 for cast-iron,
·083 for zinc (commercial),
·050? for tin (commercial),
·152 for aluminium (impure).

The value used for the latent heat of water is 80·0. This is (very nearly) the number obtained by Bunsen in 1870. Bunsen's unit of heat is the one one-hundredth part of the heat required to raise unit mass of water from 0°C. to 100°C.; this is shown by recent researches to be very nearly equal to the heat required to raise unit mass of water from 17° to 18°.*

The Time of Immersion in the Calorimeter.

In the preceding tables for iron and aluminium a variation in the time of immersion in the calorimeter produces no well-marked difference in the result. But in several series of experiments in which the time of immersion was varied I found a considerable variation in the result. For instance, a copper cylinder weighing approximately 100 grammes gave the numbers shown in the table on p. 15.

Here an increase in the time of immersion gives apparently an increased mass of ice, and from the bad conductivity of ice and the possible existence of a film of air between the metal and its ice-jacket, it might be suspected that it would take a long time for the temperature of the metal to reach that of the surrounding water. But the true explanation is different. This is at once evident when the ice is weighed during immersion. Details of a single experiment of this kind will suffice. The object experimented on was a copper sphere weighing between 62 and 63 grammes. It has already been stated that the ice-coating does not completely enclose the piece of metal. The imprisoned air always keeps open one or more passages from the interior to the exterior of the ice-coating. In the case of

* The values given in this paper for results obtained by the method of mixtures are expressed in terms of the latter unit.

Time in calorimeter in minutes.	Apparent specific heat.*
3	·0793
3	·0799
4	·0805
5	·0806
6	·0787
10	·0812
10	·0815
10	·0828
15	·0814
15	·0813
15	·0806
15	·0826
15	·0824
15	·0814
30	·0833
30	·0837
30	·0842

* The numbers in this column refer to the same cylinder as the numbers in the table of p. 6, for which the time of immersion in the calorimeter was uniformly 5 minutes. All the numbers except the last three represent early experiments. The want of agreement, specially noticeable in the immersions of 15 minutes, is no doubt largely due to the calorimeter having been sometimes used in an inefficient condition. The first five experiments have been already quoted in the footnote on p. 6.

a sphere or other well-rounded object, there is generally only a single passage, a hole of about a millimetre in diameter near the place of attachment of the thread. Through this hole a number of bubbles escape during the first two or three minutes after immersion, and these are followed at longer and longer intervals by a few other bubbles. In the present experiment, probably about five bubbles escaped during the first two minutes, and during the remainder of an hour two additional bubbles. The first weighing was made about two minutes after immersion. The interpretation of the weighings was as follows: (i.) Nine-tenths of the ice was formed during the first two minutes, and practically the whole of the ice during the first three minutes. (ii.) A bubble of volume ·06 c.c. escaped about five minutes after the moment of immersion, and a second bubble of the same volume about twenty minutes after the moment of immersion. (iii.) The ice-jacket was melting at the rate of about 3 per cent. per hour.*

The increase in the numbers of p. 15 is therefore not due to an increase in the mass of ice. The explanation seems to lie in the gradual escape of air from the ice-jacket and the replacement of this air by water leaking into the interior of the ice-jacket.†

The total mass of ice formed round the copper sphere was about 12 grammes. An addition of ·12 grammes of water exactly replacing the two bubbles of air would produce an error of one per cent. for an immersion of

* The ice-tray was not used in this experiment.

† It may be of interest to add that the small-air cavity in the case of the sphere was always formed at the top of the sphere. On the other hand, in the case of the flat-ended cylinder of p. 15, a large air-bubble, separated from the water below it by a thin film of ice, appeared at the base of the cylinder immediately after immersion; the size of this bubble gradually became less while its ice-skin increased in thickness; the final result at the base of the cylinder was in some experiments a thin film of firm ice practically in contact with the metal, in others a spongy mass of ice.

about twenty minutes. Direct experiments of the same kind as those of p. 15 gave a difference somewhat greater than this.*

I have already stated that no result of any value for the weight of ice could be obtained from the apparent weight during immersion. In the case of the copper sphere the volume of included air at the end of an hour's immersion was approximately 0·2 c.c., the actual upthrust due to ice and air being 1·1975 grammes and the upthrust calculated from the weight of the ice being about 1·03 grammes.

The time necessary for attainment of equilibrium of temperature in the ice method does not appear to differ greatly from that required in the method of mixtures (two to three minutes in the case of the objects of Tables I. to IV.).

In the experiments described in the following paragraphs I used a uniform immersion period of five minutes.

Variation of Results with the Shape and Mass of the Object.

The error due to water included within and weighed with the ice-jacket is naturally larger when the total weight of ice is smaller. This is illustrated by the following numbers for two leaden spheres weighing respectively 37 grammes and 141 grammes :—

	Apparent specific heat.
Smaller sphere	·0310 (mean of two not in good agreement).
Larger sphere	·03035 (mean of two closely agreeing).

* I do not wish to imply that the volume of water entering the ice-jacket should be equal to the volume of air escaping. It might on the contrary be expected to be rather greater.

The error due to included water also depends on the shape of the object. A spherical or well-rounded shape is favourable both to consistency and lowness of results. The following numbers for two leaden cylinders, suspended with axis vertical, and weighing respectively 64½ and 129 grammes, taken in conjunction with the above numbers for spheres, illustrate this statement:—

	Apparent specific heat.
Shorter cylinder	·0318 (mean of ·0319 and ·0317).
Longer cylinder	·03075 (mean of ·0309 and ·0306).

In the case of lead, results closely agreeing were obtained with the objects described in the following table:—

	Apparent specific heat.	
Sphere weighing 141 grammes	·0304	·0303
Cylinder with rounded ends weighing 246 grammes	·0303	·0304
Plummet with tapering rounded base weighing 286 grammes	·0303	·0303

This agreement seemed to show that the results could not be far from the truth. They were however considerably in excess of the result obtained by the method of mixtures (·02935). The only likely explanation of the discrepancy seems to be that the error due to the included water has not really been eliminated.

On account of its smaller specific heat, lead tests the capabilities of the method more severely than the metals of Tables I. to IV., and it is not surprising that the results should be less satisfactory.

Final Experiments.

As a final test of the method I made a series of experiments on various metals (two experiments for each metal). The time of transference in these experiments was five seconds, the time in the calorimeter five minutes. The piece of metal was in each case either a cylinder with rounded ends or of a compact shape approximating to this. The mass varied from 72 grammes (aluminium) to 250 grammes (lead).

In the following table the results obtained by this method are compared with the results obtained by the method of mixtures.*

	Ice method.†	Method of mixtures.*
Copper (pure)................	·0793	·0800
Lead (pure)..................	·0300	·0294
Aluminium (approx. pure)..	·1735	·1724
Nickel (approx. pure)........	·0823	·0843
Cobalt (approx. pure)........	·08365	·0843
Zinc (pure)..................	·08495	·0839
Silver (approx. pure).........	·05195	·0514
Tin (pure)...................	·05085	·0498

* *Proc. Roy. Soc.*, Vol. 72, p. 186.

† Each of the numbers in this column is the mean of two, differing from one another by more than one per cent. in only one case, that of aluminium, for which the individual results were ·1724 and ·1746. The number given for copper is the mean of two results which have been previously quoted (end of footnote on p. 9).

As might be expected from what precedes, the result given by the ice method is generally in excess of that given by the method of mixtures. The exceptions are copper, nickel, and cobalt. In the case of nickel the ice-coated cylinder was too large for the drying apparatus, and was dried by hand; the result is no doubt slightly too small on this account, probably by about one per cent.

To sum up, it appears that, with suitable precautions, results obtained by the present method will probably be within two or three per cent. of the truth. When this degree of accuracy will serve, the method may be recommended as more expeditious and much less troublesome than the method of mixtures.

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IV. Suggestions for a Revision of the Classification of the Polyclad Turbellaria.

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I. Introduction.

In dealing with the various genera and species of the Acotylean Polyclads which I have been able to examine, I have in most cases given more attention to the structure of the terminal parts of the genital ducts than to that of the other organs of the body, because I believe that they afford the readiest means by which any species may be referred to its proper genus, and at the same time they give a safe indication of the affinities of the various genera.

An examination of these organs in a considerable number of genera shows that there is much less variation in the plan on which the vagina is constructed than in the case of the male organs. In fact, the vagina of almost any Polyclad may be referred to one or other of two types; the only exception that I am acquainted with being found in the case of the specialized genus *Paraplanocera*[1]. Leaving the consideration of this genus for the present, and confining our attention to the two 'normal' types, we may take as the first that in which the vagina ends directly, at its proximal end, in the two large egg-ducts which will be spoken of as the uteri.

The vagina of this first type[2] is a perfectly simple duct, which often widens near its outer end, at the point where the shell-glands pass their secretion into it. This is the condition found in the Cotylea. In those

[1] See Note A.
[2] See Fig. 1, p. 7.

Acotylea where a vagina of this type occurs, it is usually of nearly equal calibre throughout, and the shell-glands lie along a considerable part of its length, instead of being grouped about one level. *Cestoplana*, however, amongst the Acotylea, rather recalls the Cotylean condition of the shell-glands. Any accessory organs, whether vesicular or glandular, which may occur in connection with this type of vagina are, I believe, invariably developed on the uteri.

All Cotylea are provided with a vagina of the first type, and also certain Acotylean genera: such are

Alloioplana,
Cestoplana,
Stylochus,
Hoploplana,
etc., etc.

Certain species also, belonging to genera in the majority of whose species the second type of vagina occurs, possess a vagina of this first type. Such a species is *Stylochoplana nationalis* v. Plehn ('96*a*).

THE SECOND TYPE OF VAGINA is confined to the Acotylea, though not found universally in that group. Here the vagina, after receiving the openings of the two uteri (which almost invariably combine just before they enter the vagina to form a short, median, common duct) is continued back to form what is spoken of as the accessory part of the vagina. This accessory part may be simply a vesicle opening into the vagina immediately behind the uterine opening, or it may be divided into two parts, viz.:— a long duct-like part which opens at its (morphologically) hinder end into a vesicular part; this vesicular part is usually median, but in some cases it is practically bilaterally symmetrical, of a crescentic shape with its horns directed forward, as for example in *Discocelis tigrina.*

The accessory vesicle has glandular walls, and doubtless correlated with its presence is the fact that uterine vesicles, such as are found so commonly in the Cotylea, are never found developed in connection with a vagina of the second type ; *Stylochoplana nationalis*[1], mentioned above which has a vagina of the first type, supplies an interesting example of this correlation. It is the only Acotylean species possessing uterine vesicles with which I am acquainted.

It is conceivable that the accessory vesicles may disappear altogether, and that a vagina of the first type may be produced secondarily. This reduction seems to be in progress in the genus *Leptoplana*.

The lower part of the vagina of the second type is sometimes very muscular, and may form a well-developed bursa copulatrix as in *Planocera* and some species of *Leptoplana*.

The uteri invariably open into this type of vagina from below and on its morphologically posterior side.

Turning now to the male apparatus it is found to consist normally of a muscular vesicula seminalis ; of a muscular conical penis which may be armed with a stylet, which communicates with the vesicula seminalis by means of a ductus ejaculatorius or vesicular duct, and projects into a chamber opening to the exterior, called the antrum masculinum ; and lastly of a prostate gland with muscular walls. Here again it is possible to distinguish two types of the normal apparatus, to one or other of which the majority of genera may be referred. The means used to distinguish these two types are found in the characters presented by the prostate gland.

IN THE FIRST TYPE[2] the prostate is distinct from the vesicular duct, and has a duct of its own, which

[1] This species should perhaps be made the type of a new genus.

[2] See Fig. 2, p. 7.

joins the former usually at the base of the penis. This type of apparatus is found in the majority of the Cotylea, and in many Acotylea.

IN THE SECOND TYPE[1] the prostate lies about the vesicular duct, between the vesicula seminalis and the penis, and passes its secretion into that duct. This arrangement is found in many genera of the Acotylea, *e.g.*, *Stylochoplana*, *Cestoplana*; but in the Cotylea it occurs only in *Pericelis* (:**02** p. 292) and there in a modified form.

As already stated the variations presented by these two types are much greater than those found in connection with the vagina. Thus the shape of the penis differs greatly in different genera. It reaches its greatest specialization in *Planocera* and its immediate allies, and in *Cryptocelis*. In *Discocelis* and related genera it is large and blunt, in *Enantia* it is a rounded vesicle-like body. A good idea of the differences in form exhibited by this organ may be obtained by a study of Plate 30 of Lang's monograph ('**84**).

The vesicula seminalis is found usually immediately beyond the union of the two vasa differentia. It is, in fact, a widened part of the ductus ejaculatorius, provided with muscular walls. It is occasionally absent altogether as in *Discocelis tigrina*, *Phylloplana lactea*, etc. In some such cases its place is taken by the terminal parts of the vasa differentia, which become swollen and provided with muscular walls at their distal ends. This condition is found in *Phylloplana lactea*, and also in the Latocestidæ, where we must suppose it to have arisen independently. In this latter case it is carried so far that there is a well defined pair of secondary vesicles. Such are found, too, and again quite independently, in the genus *Paraplanocera*.

[1] See Fig. 4, p. 8.

The prostate gland like the vesicula is usually provided with well-developed muscular walls. In some genera it is lost completely. Interesting stages in its reduction can be traced in the genus *Leptoplana*, whilst it has altogether disappeared in *Discocelis*, *Planctoplana* (**'92**) and in other genera of the Acotylea, and in the Diposthiidæ and Diplopharyngeatidæ amongst Cotylean forms. In some cases *e.g.*, *Discocelis*, the prostate is replaced by glands of a prostatic character which appear on the walls of the antrum. These glands in *Thalamoplana*[1] are situated at the ends of definite muscular projections from the walls of the antrum masculinum, which are of great interest, since they show how the extraordinary 'intromittent prostate' of the Diposthiidæ may have originated. In most of the Cotylea the walls of the antrum masculinum are folded so as to form a special *penis sheath*. Amongst the Acotylea this sheath occurs only in the Cestoplanidæ.

The characters discussed above, taken in conjunction with others of importance, such as the position of the tentacles or tentacle eye-groups, the presence or absence of marginal eye-spots, and the characters of the pharynx, have enabled me to draw up the following diagnostic table of the majority of the genera included in the division Acotylea. In order to make the table more complete, I have included in it the Cotylean families.

I have omitted altogether the genera *Cryptocelides* (**'93**), *Polypostia* (**'93**), and *Bergendalia* (**:03***a*) because, whilst their peculiarities enable them to be readily distinguished, they make it impossible to define their relation-

[1] A detailed account of this new genus will be published in Prof. Herdman's Report on the Pearl fisheries of Ceylon, now in the press. The genus may very briefly be defined as follows:—A genus closely allied to *Discocelis*, but with the genital apertures separated. The prostatic glands are carried on muscular projections from the walls of the antrum masculinum. Accessory vesicle crescentic.

ship to other Polyclads on our present knowledge of the group. Certain other genera, such as *Imogene*, *Diplonchus* ('84), are not sufficiently well known, and are also left out of consideration. *Polyporus* ('98), described from an immature specimen, is not included in the list, but is perhaps allied to the Stylochidæ.

I offer this revision with some diffidence, the more so that my grouping of the genera does not coincide with that given by Lang in his monograph ('84). The genera most affected belong, however, to his two families Planoceridæ and Leptoplanidæ, and, as I have already hinted (:03*b*), the discovery of such a genus as *Disparoplana* must needs modify the definition of these families. As the most important character used in my diagnosis, I have taken the condition of the prostate gland; whether provided with a duct of its own, or merely surrounding the vesicular duct, or absent altogether. The last condition is, I think, obviously a secondary one. Which of the first two is the more primitive condition it is hard to say, though the fact that the prostate with its own duct is found in the Acotylea, in practically all the Cotylea, and in such a genus as *Bergendalia*, indicates that it is, at any rate, an ancient character.

EXPLANATION OF LETTERING IN THE FIGURES.

a.m. antrum masculinum.
c. chitinous spines.
d.e. ductus ejaculatorius.
m.pr. muscular wall of the prostate.
o.s. outer muscular sheath.
p. penis.
p.s. penis sheath.
pr. prostate.
pr.c. cavity of prostate.
pr.gl. prostatic glands.
sh.gl. shell-glands.
st. stylet of penis.
ut. uterus.
va. vagina.
v.d. vas differens.
v.s. vesicula seminalis.

FIG. 1.

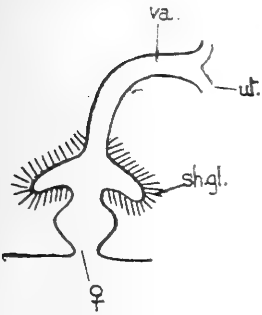

FIG. 2.

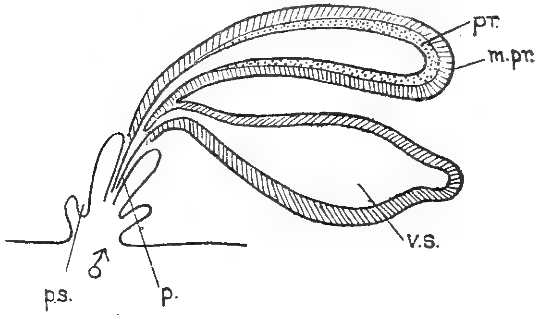

FIG. 3.

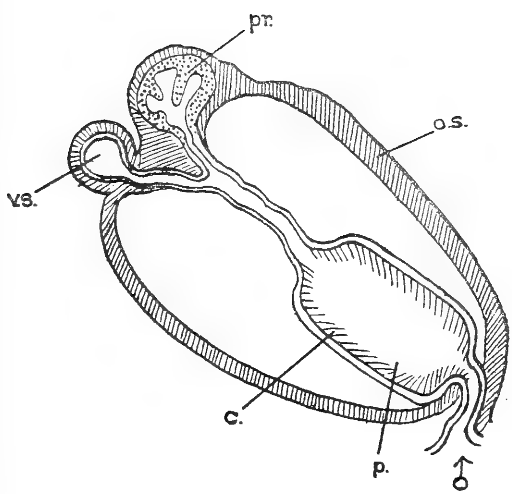

FIG. 1. Vagina of *Eurylepta cornuta* (slightly modified after Lang).
FIG. 2. Male apparatus of the same species ,, ,,
FIG. 3. ,, ,, of *Planocera simrothi* (modified after Graff).

FIG. 4.

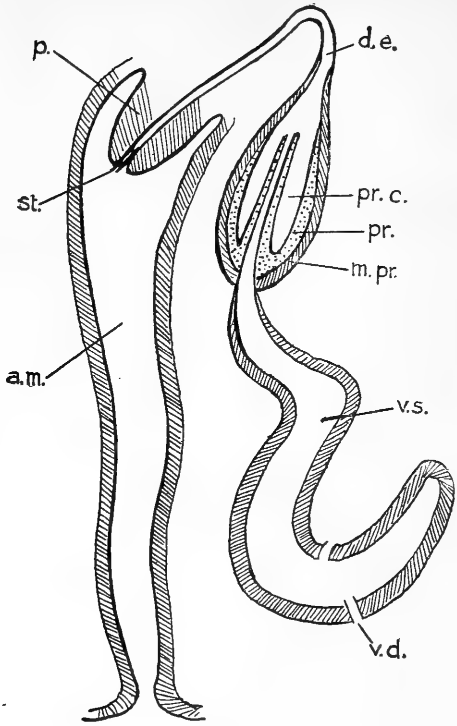

FIG. 5.

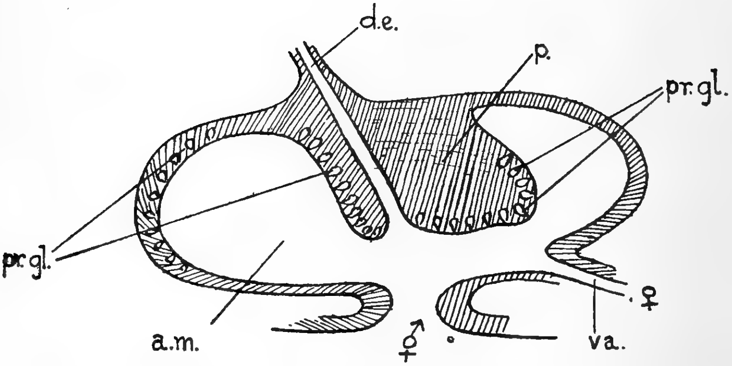

FIG. 4. Male apparatus of *Notoplana evansii* (after Laidlaw), *P.Z.S.*, 1903, i. p. 304, Fig. 51.

FIG. 5. Genital antrum of *Discocelis tigrina* showing the penis and prostatic glands (slightly modified after Lang).

II. Diagnostic Table.

ACOTYLEA.

No sucker immediately behind the female gonopore. Tentacles or tentacle eye-groups, if present, never marginal. Pharynx usually sub-central. Vagina often provided with an accessory vesicle.

I. Prostate separated from the ductus ejaculatorius and provided with a duct of its own.

A. Penis large, tubular, eversible; its lumen lined with chitinous spines. With the prostate and usually the vesicula seminalis it lies in an outer muscular sheath. No marginal eyes.

a. Nuchal tentacles present, body rounded, gut-branches few.

1. Vesicula seminalis single, lying within the outer sheath. Lower part of the vagina with thick muscular walls forming a bursa copulatrix.
Planocera (:02)[1]

2. A pair of vesiculae seminales, lying outside the outer sheath. Lower part of the vagina with a muscular, forwardly directed diverticulum.
Paraplanocera[2] (:03)

b. Body elongate, no nuchal tentacles.

1. Vesicula seminalis single, within the outer sheath, no bursa copulatrix. *Disparoplana*[2] (:03*b*)

B. Penis small conical, prostate large, its duct short, vesicula seminalis single.

a. Nuchal tentacles and marginal eyes present. Body rounded or rather elongate. (Penis without stylet?)[3]

1. Vagina without accessory vesicle, sexual openings near to each other and to the end of the body.
Stylochus.

2. Vagina and its accessory parts of great length.

[1] Where no reference is given to a genus it will be found fully described in Lang's Monograph ('84).

[2] See note A.

[3] See note B.

(α) Prostatic duct and vesicular duct opening independently, body rather long.
Idioplana ('97).

(β) Prostatic duct and vesicular duct unite at base of the penis, body round. *Woodworthia*.[1]

b. No nuchal tentacles or marginal eyes, body elongate.

1. No accessory vesicle. Penis with stylet.
Stylochocestus[1]

c. No nuchal tentacles, body elongate, accessory part of the vagina opening to the exterior. *Trigonoporus*[2]

C. Penis small, conical; a pair of vesiculæ seminales present.

1. Body rounded, pharynx sub-central, no eye-spots.
Acelis ('96)

2. Body elongate, pharynx lying far back, eye-spots numerous. *Latocestus* ('96)

II. Prostate lying about the course of the vesicular duct (ductus ejaculatorius).

A. Tentacles or tentacle eye-groups present. Pharynx sub-central, penis without a penis sheath.

a. Nuchal tentacles, no marginal eye-spots. Penis small conical, with stylet.

1. A common genital atrium. *Stylochoplana.*

2. Gonopores separated.

α. Prostate chambered.

† Antrum masculinum very long. Pharynx normal, accessory vesicle present.
Notoplana (:03*a*)

†† Antrum masculinum not very long, pharynx transversely elongate, no accessory vesicle.
Plagiotata ('96).

β Prostate not chambered, no accessory vesicle.

* Prostate very long, gonopores close together.
Alloioplana ('96).

** Prostate small, lying close about the base of the penis, antrum masculinum large and muscular. *Hoploplana* (:02).

[1] *Woodworthia*, a new genus closely allied to *Idioplana*, and *Stylochocestus*, will be described in Prof. Herdman's forthcoming report on the Ceylon Pearl-fisheries.

[2] See note C.

γ. Prostate absent. *Planctoplana* ('92).

b. No nuchal tentacles, no marginal eye-spots. Penis small conical.

1. Vesicula seminalis normal. *Leptoplana.*[1]
2. Vesicula seminalis paired, prostate reduced. *Phylloplana* (:03*b*).

B. Pharynx sub-central, no tentacles, marginal eye-spots present. Penis and prostate very large. *Cryptocelis.*

C. Pharynx behind the centre of the body, a penis sheath present, no tentacle eye-groups. Penis small.

a. Body very long, no accessory vesicle. *Cestoplana.*

b. Body rounded, accessory vesicle present, dorsal surface with numerous papillæ. *Ommatoplana* (:03).

Dorsal surface smooth (penis sheath ?). *Microcelis* ('99).

III. No internal prostate glands.

A. Pharynx sub-central, no nuchal tentacles, marginal eyes present, penis large, blunt and without a stylet.

1. External prostatic glands developed on the walls of the antrum masculinum.
   a. A common genital atrium. *Discocelis.*
   b. Genital apertures distinct. *Thalamoplana*[2].
2. No external prostatic glands, a common genital atrium. *Semonia* ('96).

B. Pharynx in the anterior half of the body, no nuchal tentacles, no marginal eye-spots. The penis which lies close behind the pharynx is a rounded vesicular body, opening through a minute antrum to the exterior.

1. Pharynx large, folded, a vesicula seminalis present, four uterine openings into the vagina. *Enantia* ('89).
2. Pharynx of a very simple type, no vesicula seminalis present, only one pair of uterine openings into the vagina. *Haploplana*[3] (:03*b*).

[1] See note D.

[2] See footnote, p. 5.

[3] See note E.

I propose to group the Acotylean genera included in the above table into families as follows :—

I. PLANOCERIDÆ.
Planocera.
Paraplanocera.
Disparoplana.

II. STYLOCHIDÆ.
Stylochinæ.
Stylochus.
Idioplana.
Woodworthia.
(*Eustylochus*).
(*Planoceropsis*).
(*Shelfordia ?*).
Stylochocestinæ.
Stylochocestus.
Trigonoporinæ.
Trigonoporus.

III. LATOCESTIDÆ.
Acelis.
Latocestus.

IV. LEPTOPLANIDÆ.
Stylochoplana.
Notoplana.
Alloioplana.
Plagiotata.
Hoploplana.
Planctoplana.
Leptoplana.
Phylloplana.

V. CRYPTOCELIDÆ.
Cryptocelis.

VI. CESTOPLANIDÆ.
Cestoplana.
Ommatoplana.

VII. DISCOCELIDÆ.
Discocelis.
Thalamoplana.
Semonia.

VIII. ENANTIIDÆ.
Enantia.
Haploplana

COTYLEA.

A sucker behind the female gonopore. Tentacles or tentacle eye-groups, if present, marginal. Vagina without accessory vesicle.

I. Pharynx sub-central.

A. Marginal eye-spots present.

a. Penes numerous, radial, no tentacles. *Anonymidæ.*

b. Penis single, a pair of small widely separated tentacles. *Pericelidæ* (:02).

B. No marginal eye-spots.

a. Prostate developed on the walls of the antrum. *Diposthiidæ* ('97).

II. Pharynx in front of the middle of the body.

A. Pharynx folded. *Pseudoceridæ.*

B. Pharynx tubular.

a. Tentacles usually present, prostate as in *Pseudoceridæ.* *Euryleptidæ.*

b. No tentacles, a pair of prostatic vesicles. *Prosthiostomidæ.*

C. Pharynx reduplicated, body very long and narrow (no sucker?) *Diplopharyngeatidæ* ('96).

III.—Notes on the Tables.

Note A.—The remarkable diverticulum of the vagina found in *Paraplanocera*, which I have figured elsewhere (:02, *fig.* 63), is quite without a parallel in any other known genus. Verrill ('88) in describing his new genus *Eustylochus* speaks of a long median duct which opens at the female orifice and runs forward to end in a flask-shaped vesicle. With this he compares a structure found in *Stylochoplana maculata*.

A careful examination of de Quatrefages' beautiful figure of this species ('45, *pl.* vi., *fig.* 2) has, however, convinced me that in this species at any rate, this median duct is nothing more than the anteriorly directed vagina (the uteri are shown opening into it) continued forward into the accessory vesicle. The fact that de Quatrefages has figured the narrow forwardly directed part of the vagina opening at the female orifice and not into the upper end of the wide distal part of the vagina is, I think, readily to be accounted for by the difficulty of determining the precise course of a duct bent upon itself, by means of optical sections only. I have not been able to examine sections of *Stylochoplana maculata*, but I feel convinced that when the genital organs of this species are so studied they will be found to resemble in detail those of *Stylochoplana agilis* as figured by Lang ('84, *pl.* 30, *fig.* 13).

In dealing with *Eustylochus*, Verrill for the same reason has not, I believe, determined the real course of the vagina, which probably differs from that of such a form as *Stylochoplana agilis* chiefly in having the uterine opening placed at a different, that is a posterior, level.

In my account of *Paraplanocera langi* I find I was in error in describing the shell-glands as lying close above the female aperture. A careful re-examination of my sections has shown that there are no shell-glands in that position in any of the three species of the genus at present known, and that the tissue which I supposed to be shell-glands, in the case of *P. langi*, though in a bad state of preservation, is probably muscular. The receptaculum seminis, as described in my account of that species, is lined with secretory epithelium. This may be held to account for the unique position of the shell-glands in *Disparoplana*, namely behind the uterine opening.

Note B.—Verrill's two genera *Eustylochus* and *Planoceropsis* are to be referred to this division ('88). *Eustylochus* appears most closely allied to *Idioplana* from the structure of its genital organs, the exact affinities of *Planoceropsis* are more doubtful. It will be noticed that both these genera are provided with nuchal tentacles and marginal eye-spots.

A recently described new genus *Shelfordia* v. Stummer-Traunfels (:02*a*) with one species, from Borneo, interesting as being the only known fresh-water Polyclad, would appear also to be related here. It has no tentacles but possesses marginal eyes. The long narrow prostate is described as ending blindly, and is said to be wound round the conical vesicula seminalis.

Note C.—The American species referred to *Trigonoporus* by Verrill ('88) can hardly remain in the genus if it is to be clearly defined. I am inclined to believe from Verrill's figure of the genital apparatus of his species (*T. folium*) that they may ultimately be found to have some affinity with *Planocera*. Certainly his figures ('88, *pl.* XLIV., *figs.* 4-7) show indications of an outer muscular sheath, whilst the backward prolongation of the vagina, save that it appears to open to the exterior, distinctly recalls the receptaculum seminis of *Paraplanocera.*

Note D.—The genus *Leptoplana* as at present constituted contains, as I have pointed out elsewhere (:03*a*), three very distinct groups. The first of these includes only *L. tremellaris*, which is unfortunately the type of the genus; the second also contains at present only one species, *L. subviridis.* The numerous remaining species form the third group which agrees much more closely with other genera of the Leptoplanidæ, in so far as the structure of the male organs is concerned, than do either of the first two groups.

Note E.—The "very small median vesicle" into which the vasa differentia of *Haploplana ellioti* open (:03) is precisely similar to the penis of *Enantia spinifera* as figured by von Graff ('89). This similarity combined with a further agreement in the position of the pharynx, which lies relatively much nearer the anterior margin than in any other Acotylean genus, are sufficient to indicate a relationship between these two genera.

IV. Literature.

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Manchester Memoirs, Vol. xlviii. (1904), *No.* **5.**

V. Report on the Recent Foraminifera from the Coast of the Island of Delos (Grecian Archipelago).

By HENRY SIDEBOTTOM.

Read October 13th. Received November 27th, 1903.

The material was procured by Mr. Nevill, of Bramall Hall, Cheshire, in the course of two cruises on board the S. Y. "Victoria" (Captain Lunham), in the years 1894, 1895, and consisted of anchor mud and dredgings; depth, eight to fourteen fathoms. The usual process of washing, floating, spinning and sifting into various sizes has been carried out. In the case of the dredgings very little washing was required, as they consisted chiefly of fine sand, shell débris, and Foraminifera. The anchor mud was composed of finer material, and lost more in weight in the process of washing, but the yield of Foraminifera in both cases was extraordinary. My brother-in-law, Mr. Nevill, very kindly examined a large quantity of the finest siftings, the examination of the rest of the material being done by myself. Mr. Nevill has also placed at my disposal a fine collection of Foraminifera from the coast at Palermo, and as they agree to a great extent with the Delos forms I have placed an asterisk before the name of the Delos species if it occurs at Palermo. I am greatly indebted to my friend, Mr. F. W. Millett, of Brixton, Devonshire, to whom my best thanks are due, both for his help in the determination of many species and for much information as regards the Foraminifera. My thanks must also be rendered to my friend, Dr. Chaster, of Southport, Mons. Chas. Schlumberger, of Paris, and Prof. A. Silvestri, of Spoleto, Italy, for their assistance and for their courtesy at all times.

February 13th, 1904.

MILIOLIDÆ.

NUBECULARIINÆ.

Nubecularia, Defrance.

***Nubecularia tibia,** Jones and Parker.

Nubecularia tibia, Jones and Parker ('60), p. 455, pl. 20, figs. 48-51. *N. tibia* (J. & P.), Brady ('84), p. 135, pl. 1, figs. 1-4.

Four specimens found with their initial chamber intact. Eight single segments also occur. Very rare.

***Nubecularia lucifuga,** Defrance. (Pl. 2, figs. 1-4).

Nubecularia lucifuga (Def.), Brady ('84), p. 134, pl. 1, figs. 9-16.

This variable species is present in great numbers. A very pretty variety (see Pl. 2, figs. 1, 2), and regular in its habit of growth, has, when fully grown, three chambers (occasionally four) covering the under surface. The test is semi-translucent, of a milky blue colour and polished. The aperture is an arched slit, running along the furthermost edge of the last chamber, from the base to halfway up the test. The complete shell consists of about ten chambers. Mr. F. W. Millett points out to me that this is an isomorph of *Carpenteria*. Frequent. Another small variety (see Pl. 2, figs. 3, 4) is present, of rather irregular lineal growth, and it always puts on a back chamber before commencing its lineal growth on the opposite side. The orifices are at the end of a group of small protuberances. Very rare.

Nubecularia divaricata, Brady. (Pl. 2, figs. 5-7).

Nubecularia divaricata, Brady ('84), p. 136, pl. 76, figs. 11-15.

The Delos forms are nearly all very large and robust, but the segments are not so much divided as shown in Brady's figures. The cement with which the various coloured sand-grains are fastened together is snow-white. Rare.

***Nubecularia bradyi,** Millett.

Nubecularia inflata, Brady ('84), p. 135, pl. 1, figs. 5-8, (*non N. inflata*, Terquem ('76), (2) 73, 8, 10*a*, *b*, *c*.) *N. bradyi*, Millett ('98), p. 261, pl. 5, fig. 6*a*, *b*.

The specimens are typical. Frequent.

MILIOLININÆ.

Biloculina, d'Orbigny.

***Biloculina irregularis**, d'Orbigny.

Biloculina irregularis (d'Orb.), Brady ('84), p. 140, pl. 1, figs. 17-18. *B. irregularis* (d'Orb.), Flint ('99), p. 295, pl. 41, fig. 3.

The specimens are not typical. The mouth is large and nearly circular, with thickened lip and T-shaped tooth. Common.

***Biloculina elongata**, d'Orbigny.

Biloculina elongata (d'Orb.), Brady ('84), p. 144, pl. 2, fig. 9.

The specimens are not so regular in growth as the one figured by Brady, the penultimate chamber being slightly constricted at the lower end, and wide and raised at the other, where it runs up to the mouth of the last chamber. Rare.

Biloculina elongata denticulate variety. (Pl. 2, fig. 8).

In this variety the base of the last chamber has five or six well marked teeth, the test also is wider than in the typical form, approaching *B. ringens* (Lam.) var. *denticulata*, Brady. Very rare.

*Biloculina ringens, Lamarck, sp.

Biloculina ringens (Lam.), Brady ('84), p. 142, pl. 2, figs. 7, 8.

The type is very rare, as with few exceptions a third chamber is slightly exposed, causing it to be triloculine.

Biloculina depressa, d'Orbigny.

Biloculina depressa (d'Orb.), Brady ('84), p. 145, pl. 2, figs. 12, 15-17, pl. 3, figs. 1, 2.

B. depressa (d'Orb.), Flint ('99), p. 294, pl. 40, fig. 1. Very rare, only two found.

Biloculina bulloides, d'Orbigny.

Biloculina bulloides (d'Orb.), Brady ('84), p. 142, pl. 2, figs. 5-6.

The one specimen found is not typical, the penultimate chamber running up to the aperture and being more flush with the last chamber than is represented in Brady's figures. Very rare.

*Biloculina tubulosa, Costa.

Biloculina tubulosa (Costa), Brady ('84), p. 147, pl. 3, fig. 6 *a*, *b*.

Only two found; the edges of the chambers are very sharp, and in one of the specimens the mouth is deformed. Very rare.

Biloculina comata, Brady.

Biloculina comata, Brady ('84), p. 144, pl. 3, fig. 9.

Only two found and they are both small. Very rare.

*Spiroloculina, d'Orbigny.

Spiroloculina planulata, Lamarck, sp.

Spiroloculina planulata (Lam. sp.), Brady ('**84**), p. 148, pl. 9, fig. 11 *a, b*. Frequent.

*Spiroloculina excavata, d'Orbigny.

Spiroloculina excavata, d'Orbigny ('**46**), p. 271, pl. 16, figs. 19-21. *S. excavata* (d'Orb.), Brady ('**84**), p. 151, pl. 9, figs. 5, 6.

Many of the specimens are of the form as figured by Brady ('84), with the exception that the neck is not quite so much produced. Frequent.

Spiroloculina dorsata, Reuss.

Spiroloculina limbata (d'Orb.), Brady ('**84**), p. 150, pl. 9, figs. 15-17.

Many of the specimens become deeply excavated, and it is a question if these should not be treated as *S. excavata*. Frequent.

*Spiroloculina impressa, Terquem. (Pl. 2, figs. 9-11).

Spiroloculina impressa (Terq.), Brady ('**84**), p. 151, pl. 10, figs. 3, 4.

The Delos form is occasionally tricarinate at the base of the last chamber. The specimens differ a good deal as to the amount of excavation. Frequent.

*Spiroloculina nitida, d'Orbigny.

Spiroloculina nitida (d'Orb.), Brady ('**84**), p. 149, pl. 9, figs. 9, 10.

Most of the specimens are of the carinate variety, and the last two chambers show more inflation than the previous ones. Brady reports it from the Mediterranean. Frequent.

*Spiroloculina grata, Terquem.

Spiroloculina grata (Terq.), Brady ('84), p. 155, pl. 10, figs. 16, 17, 22, 23.

This pretty form is well represented. Frequent.

Spiroloculina canaliculata, d'Orbigny.

Spiroloculina canaliculata, d'Orbigny ('46), p. 269, figs. 10-12.

Typical specimens are rare; specimens with only the last chamber channelled are frequent.

Spiroloculina acutimargo, Brady.

Spiroloculina acutimargo, Brady ('84), p. 154, pl. 10, figs. 12-15. *S. acutimargo* (Brady), Balkwill and Wright ('85), p. 323, fig. 1*a*, *b*, *c*.

Two only found; they come nearest to the one figured by Brady ('84), pl. 10, fig. 14, but they are a little more attenuated. Very rare.

Sigmoïlina, Schlumberger.

*Sigmoïlina tenuis, Czjzek, sp.

Spiroloculina tenuis (Czj.), Brady ('84), p. 152, pl. 10, figs. 7-11.

The Delos forms are all carinate, but they have the slight twist in the test, characteristic of the species. Rare.

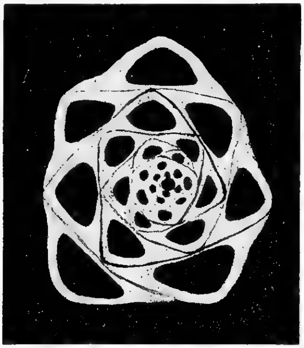
*Sigmoïlina costata, Schlumberger.

Sigmoïlina costata, Schlumberger ('93), p. 69, pl. 1, figs. 51, 52, and text-fig. 4.

The tests are all of a pale cream colour and strongly ribbed for the size of the specimens. They are more or less rough. Common.

Sigmoïlina ovata. n. sp. (Pl. 2, figs. 12, 13; Section 1).

The test in outline is an irregular oval, showing generally five chambers, but occasionally six, and there is a slight flattening on one side. Semi-opaque shell substance shows along the margin of the embracing chambers. The



No. 1. *Sigmoïlina ovata*, n. sp. × 60.
Transverse section of the test.

tooth varies from a small projection to the well-known **T**-shape. The section shows the arrangement of the chambers. M. Schlumberger kindly assisted me in the verification of this form. Common.

Miliolina, Williamson, 1858.

***Miliolina oblonga**, Montagu, sp.

Miliolina oblonga (Montg.), Brady ('84), p. 160, pl. 5, fig. 4.

Full grown specimens are large and they appear to be the same as those figured by M. Schlumberger as *Triloculina lævigata* (d'Orb.), in his monograph of the *Miliolinæ* of the Gulf of Marseilles. Common.

***Miliolina bosciana,** d'Orbigny, sp.

Quinqueloculina bosciana, d'Orbigny ('39), p. 191, pl. 11, figs. 22-24.

Mr. F. W. Millett in his report on the recent Foraminifera of the Malay Archipelago, says "A form of

M. oblonga in which the chambers are more numerous and the sutures oblique." Frequent.

Miliolina rotunda, d'Orbigny, sp.

Triloculina rotunda (d'Orb.), Schlumberger ('93), p 206, pl. 1, figs. 48-50.

The Delos form agrees well with the one figured by M. Schlumberger in the above reference, but many of them do not have the central chamber so protuberant as his drawings indicate. Frequent.

***Miliolina circularis**, Borneman, sp.

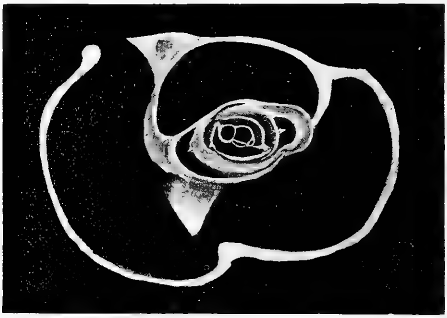
Miliolina circularis (Born.), Brady ('84), p. 169, pl. 5, figs. 13, 14.

The specimens are small, and they all have a slightly puckered-up lip on the penultimate chamber. Common.

***Miliolina subrotunda**, Montagu, sp.

Miliolina subrotunda (Mont.), Brady ('84), p. 168 pl. 5, figs. 10, 11.

The specimens are small, and not quite typical. Frequent.



No. 2. *Miliolina subrotunda*, Montagu. ×75.
Horizontal section of the test.

The forms figured by M. Schlumberger as *Quinqueloculina dilatata* (d'Orb.) ('93), p. 217, pl. 3, figs. 70-74, and pl. 4, figs. 87-90, are numerous. Yet another form of this variable species is present (Pl. 3, figs. 1-7; Section 2). The young, or biloculine form is common and the triloculine one frequent. The nearest figures I have seen of the triloculine specimens are the *Triloculina truncata*, Karrer ('64), p. 704, pl. 1, fig. 2.

*Miliolina suborbicularis, d'Orbigny, sp.

Quinqueloculina suborbicularis (d'Orb.), Schlumberger ('93), p. 73, pl. 2, figs. 63, 64, pl. 3, fig. 67 and woodcuts, 26-28. *Miliolina suborbicularis* (d'Orb.), Millett ('98), p. 502, pl. 11, fig. 13.

Present in great numbers, and many of the specimens have a hauerine tendency, showing three chambers in the last whorl. My friend, Mr. F. W. Millett, tells me this tendency appears in fossil specimens as figured by Terquem. Common.

*Miliolina marioni, Schlumberger, sp.

Triloculina marioni, Schlumberger ('93), p. 62, pl. 1, figs. 38-41, and text-figs. 7, 8.

M. Schlumberger kindly sent me specimens from the Mediterranean, and those from Delos agree with them. The groove in the centre of the back chamber, as represented in the above reference, does not show in the specimens submitted to me, nor is it present in the Delos forms. Many of them, especially in the young state, have a strong resemblance externally to *M. tricarinata*. Frequent.

*Miliolina schreiberiana, d'Orbigny, sp.

Triloculina schreiberiana, d'Orbigny ('39), p. 174, pl. 9, figs. 20-22. *T. schreiberiana* (d'Orb.), Schlumberger ('93), p. 62, pl. 1, figs. 42-44, and text-figs. 5, 6.

M. Schlumberger's figures are drawn from specimens dredged in the Gulf of Marseilles; the Delos examples of this species are similar. It appears to be nearly related to *M. trigonula*. Frequent.

*Miliolina labiosa, d'Orbigny, sp.

Miliolina labiosa (d'Orb.), Brady ('84), p. 170, pl. 6, figs. 3-5. *M. labiosa* (d'Orb.), Millett ('98), p. 502, pl. 11, figs. 8, 9.

This form seems to run into *Nubecularia bradyi*; Mr. F. W. Millett, in his Malay work, states that it ranges from *N. bradyi* to *M. valvularis*. Frequent.

*Miliolina reticulata, d'Orbigny, sp. (Pl. 3, figs. 8-10).

Miliolina reticulata (d'Orb.), Brady ('84), p. 177, pl. 9, figs. 2-4.

This handsome species occurs at Delos in three varieties. The first has a rounded periphery, the second is carinated, and in the third the keel on the last chamber splits about half way down and becomes bi-carinate. They are all beautifully reticulated. The form with the rounded periphery is the smallest of the three varieties. Frequent.

*Miliolina seminulum, Linné, sp.

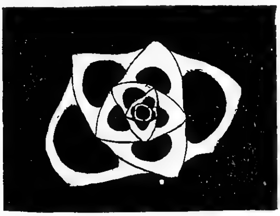
Miliolina seminulum (Linné), Brady ('84), p. 157, pl. 5, fig. 6.

The specimens run large and are highly polished. Common.

There is present also in considerable quantity a very flat variety, as shown in the figures (Pl. 3, figs. 13-15), of which the test is semi-translucent and the chamber walls thin. The mouth is very much compressed and almost closed by the long tooth.

Miliolina seminulum (Linné) var. **cornuta** nov.

(Pl. 3, figs. 11, 12; Section 3.)



No. 3. *Miliolina seminulum*, Linné var. *cornuta* nov. ×25.
Transverse section of the test.

The test is almost as broad as long, sometimes triloculine, but generally a fourth chamber just shows on the underside. The protuberances are generally situated on the edge of the last chamber in a double row, but sometimes they appear on the penultimate chamber as well. The test is stout and polished. The mouth is compressed at the sides and the tooth is large and prominent.

The section shows the arrangement of the chambers. Frequent.

Miliolina vulgaris, d'Orbigny.

Quinqueloculina vulgaris (d'Orb.), Schlumberger ('93), p. 65, figs. 13, 14, pl. 2, figs. 65, 66.

The specimens are not so fully developed as those shown in the above reference, the test being not so broad and the edges of the chambers sharper. Common.

***Miliolina auberiana**, d'Orbigny, sp.

Miliolina auberiana (d'Orb.), Brady ('84), p. 162, pl. 5, figs. 8 *a*, *b*, 9.

The Delos forms of this variety of *M. seminulum* are not so broad in comparison with the length as those figured by Brady, otherwise they agree well. Frequent.

***Miliolina cuvieriana**, d'Orbigny, sp.

Miliolina cuvieriana (d'Orb.), Brady ('84), p. 162, pl. 5, fig. 12 *a*, *b*, *c*. *M. cuvieriana* (d'Orb.), Millett ('98), p. 505, pl. 12, fig. 2 *a*, *b*.

The unornamented specimens are small, with very few exceptions. Common.

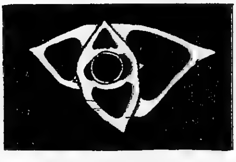
*The *Q. seminuda* of Reuss with the rounded periphery striated, is also present, along with those which have the periphery square and costate; the test of the latter ones is generally more compressed. Both are small. Frequent.

***Miliolina boueana**, d'Orbigny, sp.

Quinqueloculina boueana, d'Orbigny ('46), p. 293, pl. 19, figs. 7-9. *M. boueana* (d'Orb.), Brady ('84), p. 173, pl. 7, fig. 13.

The neatness and compactness of the Delos form, together with the comparative boldness of the costæ, incline me to think that this is a young and triloculine condition of the above. Common.

***Miliolina lævigata**, d'Orbigny, sp. (Pl. 4, figs. 1-3; Section 4).



No. 4. *Miliolina lævigata*, d'Orb. ×40.
Transverse section of the test.

Adelosina lævigata, d'Orbigny ('**46**), p. 302, pl. 20, figs. 22-24. *A. lævigata* (d'Orb.), Schlumberger ('**86**), p. 549, fig. 6, pl. 16, figs. 19-21.

The amount of tilting of the central chamber varies considerably, and the last chamber is sometimes very faintly striated. The test is polished. Frequent.

***Miliolina undosa**, Karrer, sp.

Miliolina undosa (Karrer), Brady ('**84**), p. 176, pl. 6, figs. 6-8.

In the Delos form all the edges of the chambers are striated, and the striæ often run down the sides of the chambers. Frequent.

Miliolina undulata, d'Orbigny.

Quinqueloculina undulata (d'Orb.), Schlumberger ('**93**), p. 213, pl. 2, figs. 61, 62.

The specimens agree with the above reference. Common.

***Miliolina pygmæa**, Reuss, sp. (Pl. 4, figs. 4-6).

Miliolina pygmæa (Reuss), Brady ('**84**), p. 163, pl. 113, fig. 16 *a*, *b*.

The test is slightly roughened, the mouth circular and toothed. Frequent.

Miliolina contorta, d'Orbigny, sp.

Quinqueloculina contorta, d'Orbigny ('**46**), p. 298, pl. 20, figs. 4-6.

The test is not polished, but is slightly rough. The neck is rather more produced than in d'Orbigny's figures. Frequent.

The specimens (Pl. 4, figs. 7-9) I have figured are apparently a feeble variety of this variable species. Common.

***Miliolina sclerotica,** Karrer, sp.

Quinqueloculina sclerotica, Karrer ('68), p. 152, pl. 3, fig. 5.

This appears to be a rough form of *M. contorta.* The nearest figures to the Delos form which I have seen, are those by M. Schlumberger, under the name *Quinqueloculina rugosa*, d'Orbigny ('93), p. 210, pl. 4, figs. 91-93. Frequent.

***Miliolina stelligera,** Schlumberger, sp.

Quinqueloculina stelligera, Schlumberger ('93), p. 68, pl. 2, figs. 58, 59, and text-fig. 17.

M. Schlumberger very kindly sent me specimens from the Gulf of Marseilles, and those from Delos are similar. Frequent.

***Miliolina gracilis,** d'Orbigny, sp. (Pl. 4, figs. 10-12).

Triloculina gracilis, d'Orbigny ('39), p. 159, pl. 11, figs. 10-12.

All the specimens are keeled, and the test is striated. The striæ do not follow the curves of the chambers the whole way down, but run more or less obliquely across them. The walls of the chambers are thin and fragile. Frequent.

***Miliolina agglutinans,** d'Orbigny, sp.

Miliolina agglutinans (d'Orb.), Brady ('84), p. 180, pl. 8, figs. 6, 7.

The form of the test comes nearest to *M. sclerotica.* Many of the tests are very rough, fragments of what look like minute pieces of coal being mixed up with the sand grains. Common.

***Miliolina bicornis,** Walker and Jacob, sp. (Pl. 4, figs. 13, 14).

Miliolina bicornis (W. and J.), Brady ('84), p. 171, pl. 6, figs. 9, 11, 12. *Adelosina bicornis* (W. and J.), Schlumberger ('86), pp. 546-552, figs. 1-5, 7 and 8, pl. 16, figs. 10-15.

This is one of the largest of the Delos *Miliolinæ.* In one case the test has opened out, forming very nearly an equilateral triangle, and thus approaching in mode of growth *M. separans.* Frequent.

*__Miliolina disparilis__, d'Orbigny, sp.

Quinqueloculina disparilis (d'Orb.), Schlumberger ('93), p. 70, pl. 2, figs. 55-57.

These are well figured by M. Schlumberger in the above reference. Common.

*__Miliolina costata,__ d'Orbigny, sp.

Quinqueloculina costata (d'Orb.), Schlumberger ('93), p. 69, fig. 20, pl. 3, figs. 75, 76.

In some cases the costæ are absent on the face of the chamber. Common.

Miliolina pulchella, d'Orbigny, sp. (Pl. 4, fig. 15).

Miliolina pulchella (d'Orb.), Brady ('84), p. 174, pl. 6, figs. 13, 14. *Adelosina duthiersi*, Schlumberger ('86), pp. 553, 554, fig. 9, pl. 16, figs. 16-18.

This large and handsome Foraminifer varies a great deal as to its ornamentation; in some of the specimens the fine striæ are almost absent, and the bold costæ much broken up. Very rare.

Miliolina linnæana, d'Orbigny, sp.

Quinqueloculina josephina, d'Orbigny ('46), p. 297, pl. 19, figs. 25-27. *M. linnæana* (d'Orb.), Brady ('84), p. 174, pl. 6, figs. 15-20.

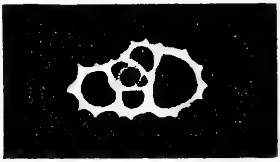
Judging from outward appearances, *M. linnæana* is an intermediate form between *M. pulchella* and *M. bicornis.* Rare.

HAUERININÆ.

Articulina, d'Orbigny.

Articulina sulcata, Reuss. (Pl. 4, figs. 16, 17; Section 5).

Articulina sulcata (Reuss), Brady, Parker and Jones (**'88**), p. 215, pl. 40, fig. 11. *A. sulcata* (Reuss), Brady (**'84**), p. 183, pl. 12, figs. 12, 13. *A. sulcata* (Reuss), Egger (**'93**), p. 243, pl. 3, fig. 5.

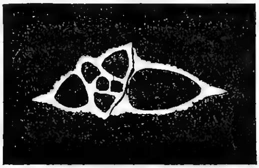


No. 5. *Articulina sulcata*, Reuss. ×75.
Transverse section of the test.

This form as figured by Brady, and about which he raises the question as to its being a distinct species, or only the young form of one of the other species, is present in considerable quantity. A few of the specimens with apparently the same commencement, have another chamber added, after the manner of *A. sagra* or *A. conico-articulata.* The mouth is compressed (with the exception of three specimens, in which it approaches roundness), and it is a question if they should not be placed with *A. sagra.* The form figured by Brady, Parker and Jones, under the name *A. sulcata* comes very near to Pl. 4, fig. 19, which I have placed under *A. sagra.* It may be noted that near the base of the final chamber of the specimens as represented in Pl. 4, fig. 17, it becomes sometimes nearly round in section, as in *A. conico-articulata*, the mouth remaining flattened. The *Articulina gibbosula*, d'Orbigny (**'46**), p. 282, pl. 20, figs. 16-18, is almost similar to these. It is possible that they should be placed under *A. conico-articulata*, but the milioline commencement is very much larger than in any I have seen of this species, and as this commencement appears to be a facsimile of Brady's figures I have put them under *A. sulcata.*

Milioline part common, with chamber added very rare.

Articulina sagra, d'Orbigny. (Pl. 4, figs. 18-20; Section 6.)



No. 6. *Articulina sagra*, d'Orb. ×75.
Transverse section of the test.

Articulina sagra, d'Orbigny ('39), p. 183, pl. 9, figs. 23-26.

A. sagra (d'Orb.), Brady ('84), p. 184, pl. 12, figs. 22-24.

The milioline commencement in the Delos forms is nearly always more or less keeled and only a few of the specimens have one lineal chamber added.

Looking at the whole of the Delos specimens together, viz., *A. sulcata* and *A. sagra*, it seems to me that they could very well be placed under the latter name. Only two large ones were found. (Pl. 4, fig. 18.) Frequent.

Articulina lineata, Brady. (Pl. 5, fig. 1.)

Articulina lineata, Brady ('84), p. 183, pl. 12, figs. 19-21.

Brady speaks of this as being a rare species, about twenty have been found in the Delos material. In two cases the added chamber is smooth. Rare.

Vertebralina, d'Orbigny.

***Vertebralina striata**, d'Orbigny.

Vertebralina striata (d'Orb.), Brady ('**84**), p. 187, pl. 12, figs. 14-16.

This species is present in great numbers and in all stages of growth. Many are of large size, and some of them boldly striated and pitted as in *V. insignis*. Common.

Massilina, Schlumberger.

***Massilina secans**, d'Orbigny, sp.

Massilina secans (d'Orb.), Schlumberger ('**93**), p. 218, figs. 31-34, pl. 4, figs. 82, 83. *M. secans* (d'Orb.), Goës ('**94**), p. 112, pl. 20, fig. 856.

This occurs in two forms, the one which is frequent has the periphery plain, and the other, which is rare, has it beautifully denticulated ; this latter form is well figured by M. Schlumberger.

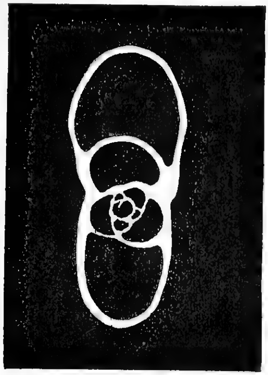
Massilina annectens, d'Orbigny, sp. (Pl. 5, figs. 2-4).

Massilina annectens, Schlumberger ('**93**), p. 220, pl. 3, figs. 77-79.

The tests are nearly as wide as they are long, deeply excavated on one side, and with the chamber on the side opposite to this excavation very protuberant and angular. Frequent.

Massilina rugosa, n. sp. (Pl. 5, figs. 5, 6; Section 7.).

The test of this form is rough and compressed, and the two final chambers embracing. The amount of exposure of the third chamber varies slightly, and in one or two cases a fourth one shows. The mouth is very large and heavily bordered, and the tooth strong and



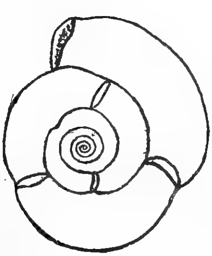
No. 7. *Massilina rugosa*, n. sp. × 50.
Transverse section of the test.

prominent. The section shows the arrangements of the chambers. I am indebted to M. Schlumberger for his help in the identification of this species. Frequent.

Hauerina, d'Orbigny.

Hauerina compressa, d'Orbigny. (Pl. 5, figs. 7, 8 ; Cut 8).

Hauerina compressa, d'Orbigny ('**46**), p. 119, pl. 5, figs. 25-27. *H. compressa* (d'Orb.), Brady ('**84**), p. 190, pl. 11, figs. 12, 13.

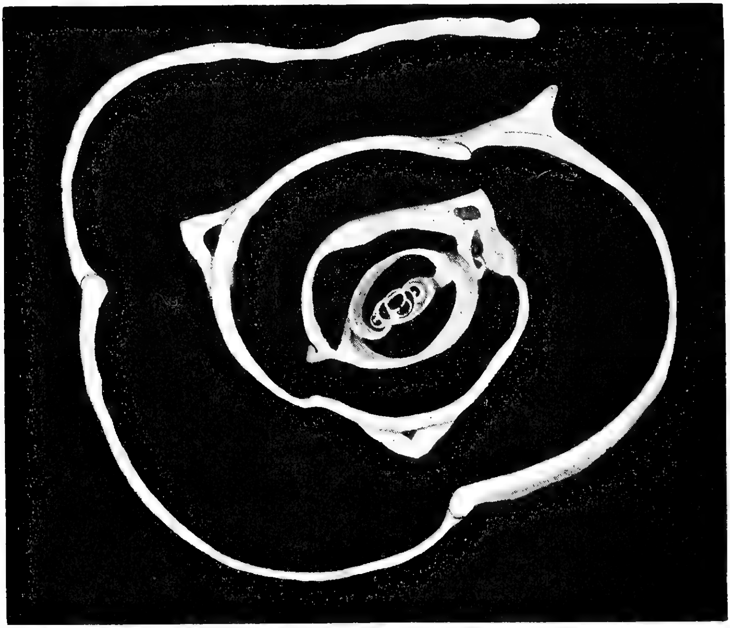


No. 8. *Hauerina compressa,* d'Orb. × 75.
Mounted in Canada balsam, and viewed by transmitted light.

The test is semi-translucent and slightly compressed, and has a cribrate aperture which seems to be formed of very minute sand grains. I have been much puzzled concerning this form and by the different opinions expressed as to its identity, and feel I cannot do better than accept M. Schlumberger's decision that it is a *Hauerina* of megalospheric form A, and is most probably *H. compressa*, d'Orbigny. Frequent.

Planispirina, Seguenza.

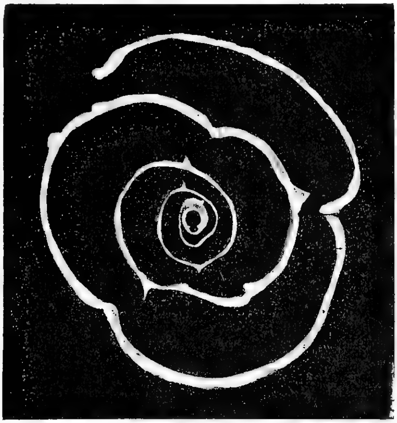
Planispirina schlumbergeri, n. sp. (Pl. 5, figs. 9-11; Section 10).



No. 10. *Planispirina schlumbergeri*, n. sp. × 50.
Horizontal section of the test.

Test compressed, chambers embracing, the last three nearly covering the earlier ones, periphery round. The mouth is large and toothed. It gives me much pleasure to associate M. Schlumberger's name with this form. The drawings and section were submitted to him for inspection. Rare.

Planispirina striata, n. sp. (Pl. 5, figs. 12-14; Section 9.)



No. 9. *Planispirina striata*, n. sp. × 50.
Horizontal section of the test.

This handsome form is frequent in these dredgings. The test is compressed, the underside much flattened, as if the test had been adherent; the chambers are convex on the upperside, besides being more embracing than they are underneath. They are beautifully but irregularly striate, the striation following their curvature. On the underside these striæ are not so marked. The test is polished and thin and the underside is semi-translucent. The mouth is heavily lipped, and is partially closed by the flap on the anti-penultimate chamber. The section shows the arrangement of the chambers, the last few of which are constricted at their ends. Frequent.

PENEROPLIDINÆ.

Peneroplis, Montfort.

Peneroplis pertusus, Forskål, sp.

*Var *a. planatus*, Fichtel and Moll, sp. Very common.
„ *b. pertusus*, Forskål, sp. Rare.
* „ *c. arietinus*, Batsch, sp. Frequent.
„ *d. cylindraceus*, Lamarck, sp. Frequent.
„ *e. lituus*, Gmelin, sp. Does not occur.
„ *f. carinatus*, d'Orbigny. Very rare.
* „ *g. lævigatus*, Karrer. Rare.

The above arrangement is taken from Brady ('84), pl. 13, figs. 12-25.

Brady states in the Challenger work, that "as regards *Peneroplis pertusus* and its varieties nothing can be more easy than to pick out a number of striking specimens and give to each a distinctive name, but in no other way can they be divided into species," and as regards the Delos forms, var. *f.* may be only the young of var. *g.*, *lævigatus* being in some cases a stout nautiloid form at its commencement, and becoming thin and complanate as the growth enlarges. In these gatherings var. *f.* is never larger than the spiral commencement of var. *g.* Var. *a.* is present in great quantity, and is large. Var. *d.* is often very long, having as many as eleven chambers in the lineal series. Some of the specimens are stout and coarse, and others just the reverse.

Orbitolites, Lamarck.

Orbitolites marginalis, Lamarck, sp.

Orbitolites marginalis (Lamk.), Carpenter ('83), p. 20, pl. 3, figs. 1-7; pl. 4, figs. 1-5. *O. marginalis* (Lamk.), Brady ('84), p. 214, pl. 15, figs. 1-5.

The specimens are small. Frequent.

Orbitolites duplex, Carpenter.

Orbitolites duplex, Carpenter ('83), p. 25, pl. 3, figs. 8-14; pl. 4, figs. 6-10; pl. 5, figs. 1-10.

The specimens are small and seldom exceed one-eighth of an inch in diameter. The double row of pores shows distinctly on the edge of the disk. These pores lie in depressions, but the ridges between them are not developed as in the typical form. The upper and lower rows of pores do not lie opposite one another but alternate. Carpenter ('83, p. 43) in his "concluding summary, with a study of the theory of descent" of the Orbitolites, states, "*First*, that the remoter ancestry, instead of being indicated (as it commonly is in the developmental history of the higher organisms) by obscure and transitory phases, is here distinctly represented in the earlier stages of the completed form. Thus, if the development of a very young *Orbitolites tenuissima* were checked in its early Milioline stage it would be accounted a *Spiroloculina;* if checked in its short Peneropline stage, it would be accounted a true *Peneroplis*; and if checked in its Orbiculine stage, it would be accounted a true *Orbiculina.* And so, if the development of the "sub-typical" variety of *Orbitolites complanata* were checked in its first stage, it would rank as *Orbitolites marginalis*; if checked in its second, as an *Orbitolites duplex*; and if checked in its third, as the earlier (fossil) form of *Orbitolites complanata.*"

This shows the difficulty that arises in attempting to separate specimens into their respective species. Frequent.

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EXPLANATION OF PLATES.

PLATE II.

Figs. 1, 2.	*Nubecularia lucifuga*, Defrance.	× 50.
,, 3, 4.	,, ,, ,, var.	× 50.
,, 5-7.	,, *divaricata*, Brady.	× 50.
,, 8.	*Biloculina elongata*, d'Orb., denticulate var.	× 50.
,, 9-11.	*Spiroloculina impressa*, Terquem.	× 50.
,, 12, 13.	*Sigmoïlina ovata*, n. sp.	× 50.

PLATE III.

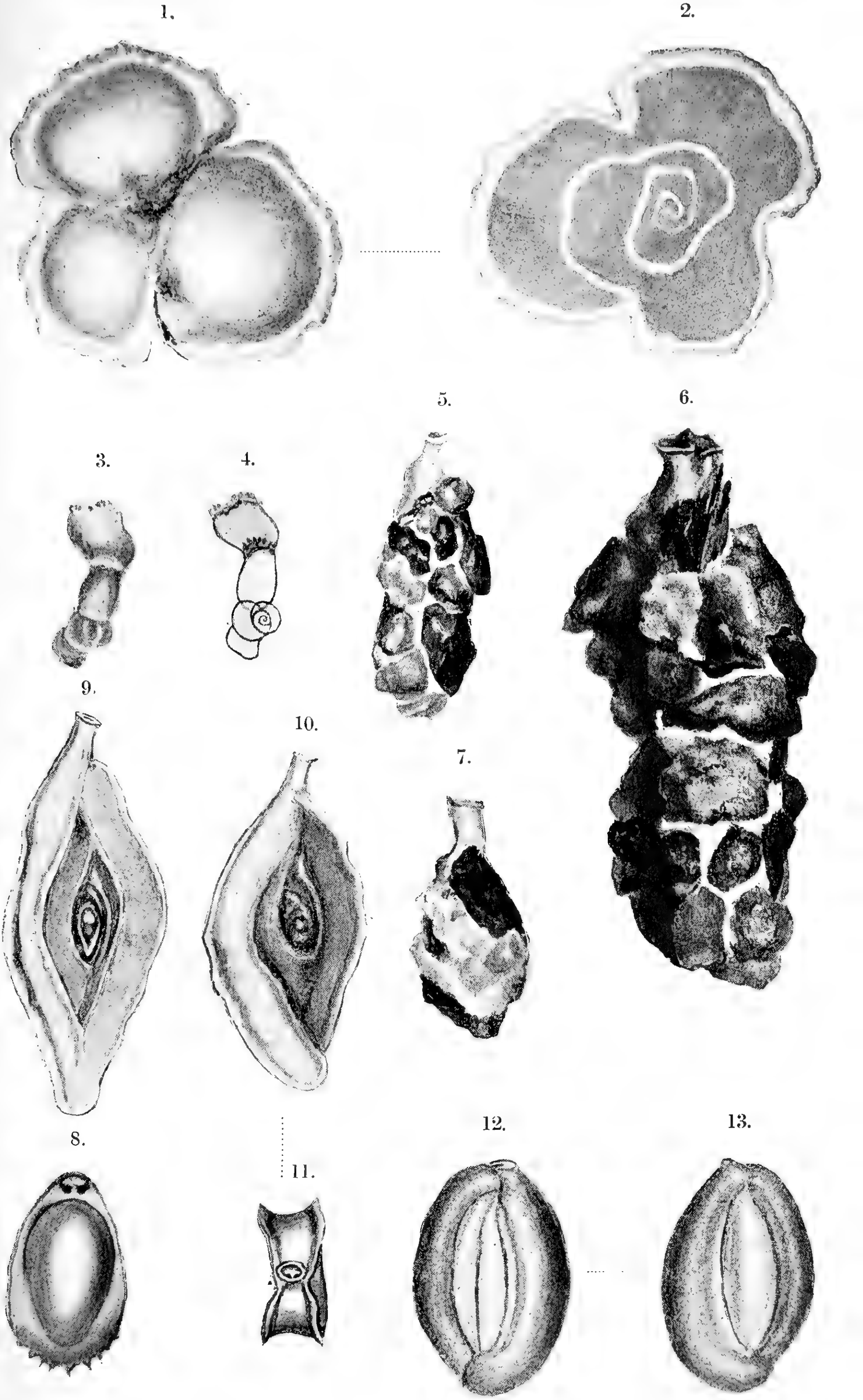
Figs. 1-7.	*Miliolina subrotunda*, Montagu, sp.	× 50.
,, 8-10.	,, *reticulata*, d'Orbigny, sp.	× 25.
,, 11, 12.	,, *seminulum*, Linné, sp. var. *cornuta*, nov.	× 25.
,, 13-15.	,, *seminulum*, Linné, sp.	× 50.

PLATE IV.

Figs. 1-3.	*Miliolina lævigata*, d'Orbigny.	× 25.
,, 4-6.	,, *pygmæa*, Reuss, sp.	× 50.
,, 7-9.	,, *contorta*, d'Orbigny.	× 50.
,, 10-12.	,, *gracilis*, d'Orbigny, sp.	× 50.
,, 13, 14.	,, *bicornis*, Walker and Jacob, sp.	× 25.
,, 15.	,, *pulchella*, d'Orbigny, sp.	× 25.
,, 16, 17.	*Articulina sulcata*, Reuss.	× 50.
,, 18-20.	,, *sagra*, d'Orbigny.	× 50.

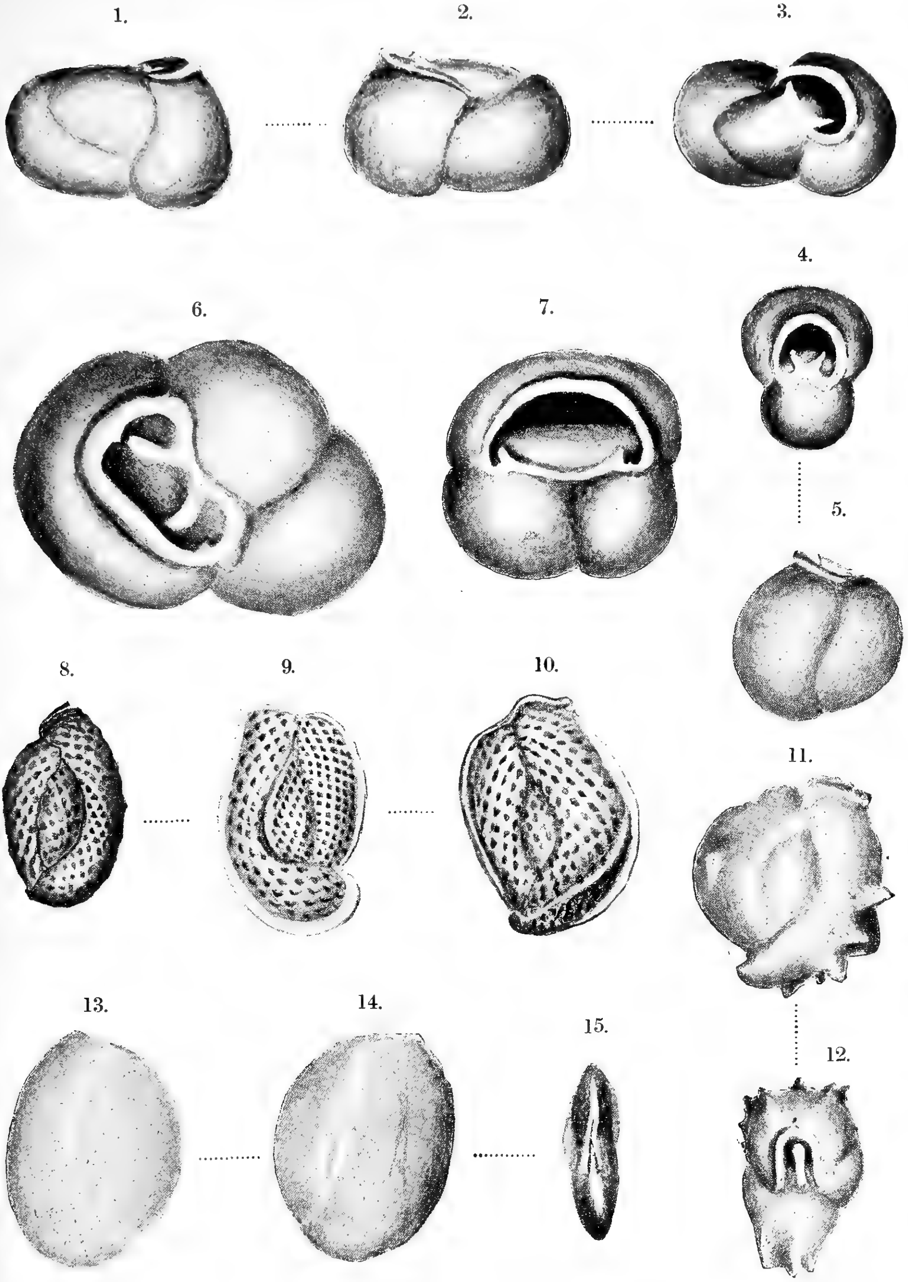
PLATE V.

Fig. 1.	*Articulina lineata*, Brady.	× 50.
,, 2-4.	*Massilina annectens*, d'Orbigny, sp.	× 25.
,, 5, 6.	,, *rugosa*, n. sp.	× 50.
,, 7, 8.	*Hauerina compressa*, d'Orbigny.	× 75.
,, 9-11.	*Planispirina schlumbergeri*, n. sp.	× 25.
,, 12-14.	,, *striata*, n. sp.	× 50.



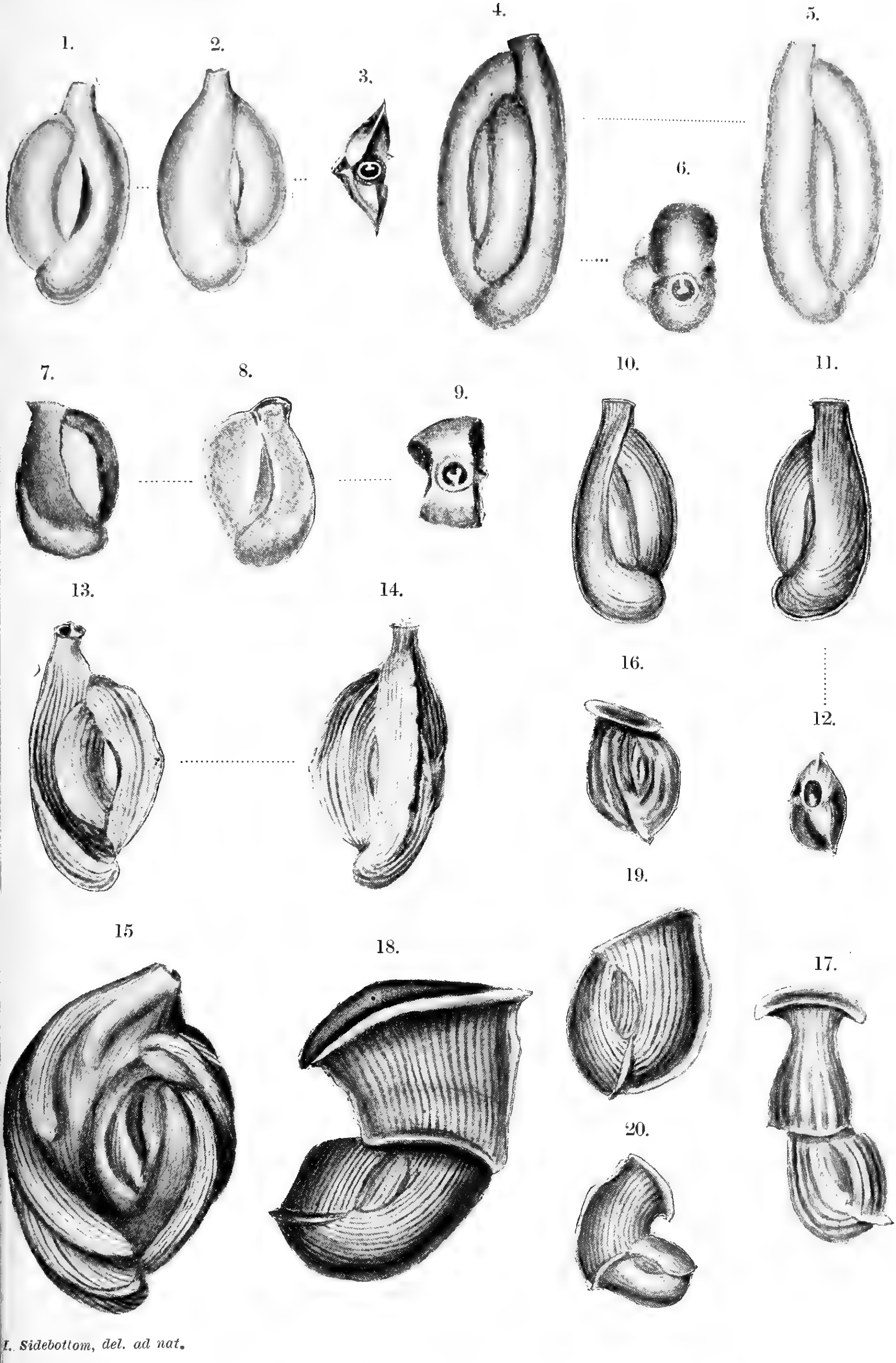
H. Sidebottom, del. ad nat.

Foraminifera from the coast of the island of Delos.

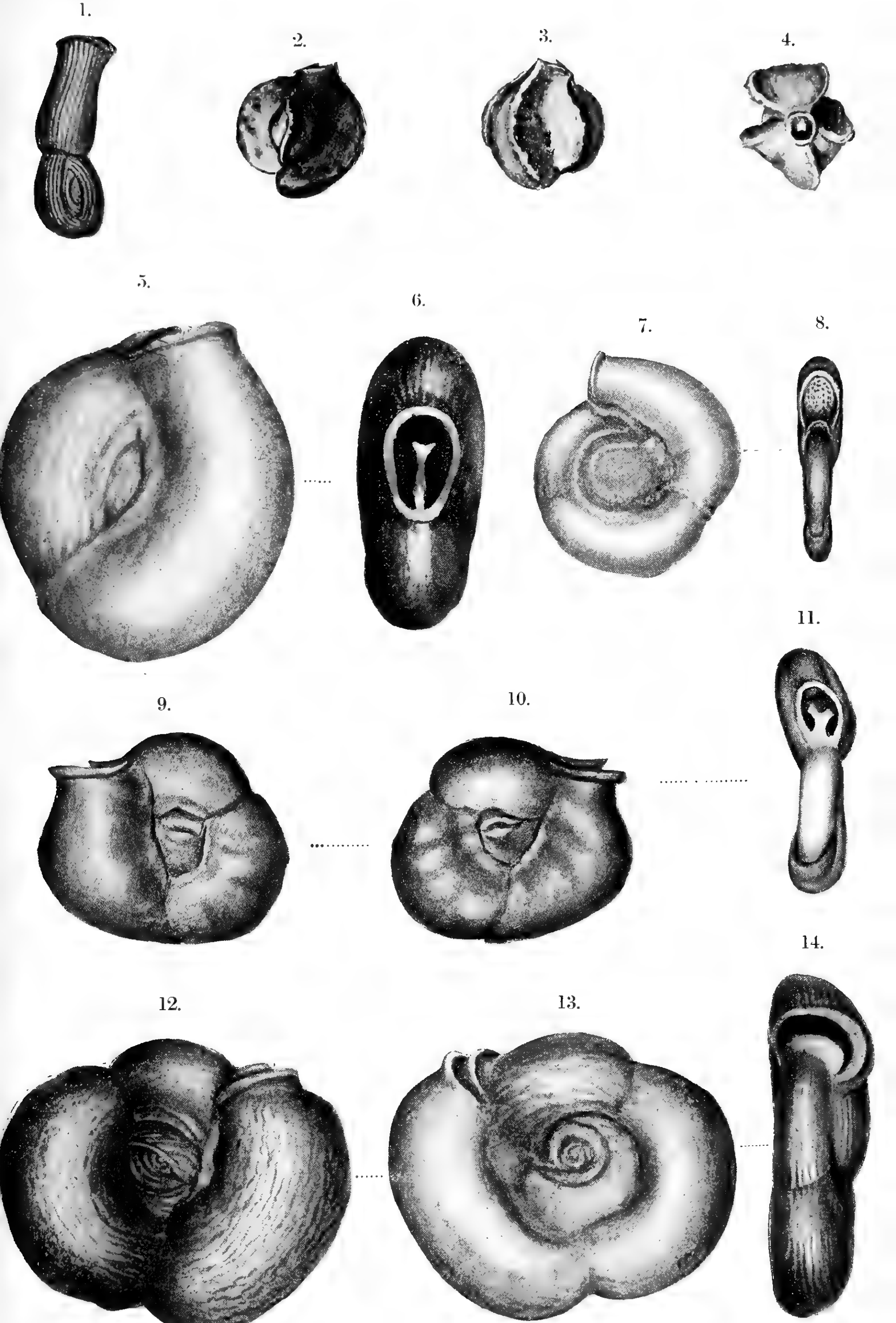


H. Sidebottom, del ad nat.

Foraminifera from the coast of the island of Delos.



Foraminifera from the coast of the island of Delos.



H. Sidebottom, del. ad nat.

Foraminifera from the coast of the island of Delos.

Manchester Memoirs, Vol. xlviii. (1904), *No.* 6.

VI. On the Specific Heats and Specific Volumes of Certain Alloys.

By H. E. SCHMITZ, M.A., B.Sc.

Received and read January 15th, 1904.

Among the various methods that have been used for the study of the constitution of alloys, the determination of the specific heat has attracted but little attention. It is in fact generally assumed that the specific heat at ordinary temperatures of any alloy that does not fuse near 100° C. follows the law enunciated by Regnault* as the result of his study of certain alloys of lead-tin, lead-antimony, bismuth-tin, bismuth-tin-antimony and bismuth-tin-antimony-zinc. Most of the published values for the specific heat of alloys are in accordance with Regnault's law,† but certain measurements by Laborde‡ show that the alloys of iron-antimony are exceptional. Laborde's results indicate a compound Fe_3Sb_4, and the same or nearly the same compound is indicated by the diagram of specific volume.§

Certain apparently anomalous values obtained by myself led me to examine several alloys that appeared to promise interesting results. The results obtained are on the whole confirmatory of Regnault's law, but, as the mass of available data is by no means large, it may be useful to place them on record. Any real deviations from the law must almost certainly be small|| and therefore difficult to detect. I hope in the future by the application of other

**Ann. de Chim. et de Phys.*, 1841, Vol. 1, p. 183.

†See for instance: Tomlinson, *Proc. Roy. Soc.*, 1885, Vol. 38, pp. 497-8; Tilden, *Phil. Trans. A.*, 1900, Vol. 194, pp. 244-5; Landolt and Börnstein's "Tables," second edition, p. 324; and for low temperature determinations Behn, *Ann. d. Physik*, 1900, Vol. 1, pp. 260-2.

‡*Journal de Physique*, 1896, Vol. 5, p. 547.

§Maey, *Zeitschr. Phys. Chem.*, 1901, Vol. 38, p. 302.

||Laborde's hypothetical compound has a specific heat about 3 per cent. in excess of the calculated specific heat.

March 2nd, 1904.

methods to investigate more completely certain apparently exceptional cases not dealt with in the present paper.

The specific volumes as well as the specific heats of the specimens have been determined. As pointed out by Maey,* the non-agreement or agreement of the specific volume with that calculated from the law of mixtures, indicates the existence or non-existence of a chemical compound.

Analyses of the alloys were kindly undertaken by Mr. J. Race. Where, as in the work now recorded, alloys are prepared on a small scale, it is in some cases not easy, even if several analyses are made, to obtain satisfactory evidence as to whether or not the specimen is of uniform composition throughout. In such cases the proportions of materials used may represent the average composition better than the results of analysis. In the following pages computed values for specific heat or specific volume are distinguished by letters in brackets as follows :—

(*a*) computed from analysis,

(*b*) computed from proportions of materials used,

(*c*) computed from atomic proportions.

Most of the alloys examined were prepared from the pure or nearly pure metals.† To ensure more perfect mixing, the first casting was reversed and remelted at least once. The metals were melted and mixed in a fireclay or carbon crucible in a small gas-furnace, with or without an appropriate flux, and cast in a cylindrical iron mould (1¼ inches internal diameter). The prepared specimen was about one inch in diameter; it was made as long as the nature of the particular casting would allow. My thanks are due to Mr. F. W. Parrott for his careful attention to the details of this part of the work.

**Zeitschr. Phys. Chem.*, 1901, Vol. 38, pp. 292-306.

†Copper, zinc and tin practically pure. Analysis of aluminium by Mr. Race: copper 0·05, zinc 0·05, lead 0·02, iron 0·02, magnesium 0·01, silicon 0·03, aluminium (by difference) 99·82.

The following table gives the specific heats, densities and specific volumes of the chief constituents of the alloys.

Metal.	Specific Heat.	Density.	Specific Volume.
*Aluminium, over $99\frac{1}{2}$ per cent., cast	·2191	2·671 (13°)	·3744 (13°)
†Copper, pure, cast	·0936	8·550 ($16\frac{1}{2}$°)	·1170 ($16\frac{1}{2}$°)
†Zinc, pure, cast	·0931	7·117 (19°)	·1405 (19°)
†Tin, pure, cast	·0552	7·291 (18°)	·1372 (18°)

Some of the alloys examined contain small proportions of iron, bismuth and lead. For these metals the following approximate values are used:

Metal.	Specific Heat.	Density.	Specific Volume.
Iron	·113	7·9	·127
Lead	·0305	11·4	·088
Bismuth	·0305	9·8	·102

The specific heats given in the first table are from a former paper.‡ They are for the approximate range 20° C. to 100° C. The specific heats of alloys given in the following pages have been very carefully determined by the same method and with the same apparatus,

*From the British Aluminium Company.

†From Messrs. Johnson, Matthey and Co.

‡*Proc. Roy. Soc.*, Vol. 72, pp. 192-3.

so that they should be strictly comparable with the determinations for the elements. As a test of the comparability of the present with the former series, I made two new determinations for a specimen of commercial aluminium included in the previous series, with the following results :

Former series	·1917 (exp. 1)
	·1914 (exp. 2)
Present series	·1913 (exp. 1)
	·1922 (exp. 2)

The specific volumes given in the present paper have been carefully determined by weighing in air and in distilled water. The specimen was boiled in the water where want of smoothness of the surface (or the suspected existence of small holes) made such a course desirable. The usual corrections for the buoyancy of air and the density of water have been made, and the capillary pull on the suspending thread has been allowed for. The values given are in cubic centimetres (at the temperature of observation, given in brackets) per gramme.

Copper-Tin.

Several methods of investigation have indicated the existence of a true compound Cu_3Sn.* The specific heat of this alloy does not seem to have been previously determined. It was therefore a matter of interest to find whether the specific heat, in this well-established case of chemical combination, would show any measurable deviation from Regnault's law. My results, given in the following table, do not indicate any such deviation.

*See for instance: Riche, *Ann. de Chim. et de Phys.*, 1873, Vol. 30, p. 416; Roberts-Austen, Phil. Mag., 1879, Vol. 8, pp. 551-3; Le Chatelier, *Comptes Rendus*, 1895, Vol. 120, pp. 835-6, and *Annales des Mines*, 1897, Vol. 11, p. 201; Stansfield, *Proc. Inst. Mech. Eng.*, 1895, pp. 269-279; Herschkowitz, *Zeitschr. Phys. Chem.*, 1898, Vol. 27, pp. 148 and 165; Maey, *Zeitschr. Phys. Chem.*, 1901, Vol. 38, pp. 301-2; B. A. Report, 1901, pp. 75-78.

Specific heat found.	Specific heat calculated.
·0784 (exp. 1)	·0786 (*a*)
·07855 (exp. 2)	·0787 (*b*)
	·07885 (*c*)

The atomic weights assumed for the calculated value (*c*) are Cu 63·6, Sn 119·0. In preparing the alloy a slightly higher proportion of tin than that required by the formula was taken (38·7 per cent. instead of 38·4 per cent.): an analysis gave 38·94 per cent. of tin.

The experimental and calculated specific volumes are shown in the next table. The value found is in fair

Specific volume found.	Specific volume calculated.
·1121 (17°)	·1249 (*a*)
	·1248 (*b*)
	·1248 (*c*)

agreement with that recently given by Maey,* but, as this writer points out, some of the earlier measurements for copper-tin differ considerably. I therefore prepared a second specimen of the alloy, using a slightly smaller excess of tin and cooling the molten alloy more slowly. This specimen gave for the specific volume ·1119 (17°). Thus the contraction is 10·2 per cent. (first specimen) or 10·3 per cent. (second specimen).

**Zeitschr. Phys. Chem.*, 1901, Vol. 38, p. 291.

Aluminium Alloys.

The following table shows the results obtained for certain alloys of aluminium:

Approximate Composition.	Specific Heat.		Specific Volume.	
	Found.	Calculated.	Found.	Calculated.
Aluminium..80 Copper.......20	·1935 (exp. 1) ·1935 (exp. 2)	·194 (*a*) ·194 (*b*)	·3224 ($19\frac{1}{2}^\circ$)	·323 (*a*) ·323 (*b*)
Aluminium..60 Copper.......40	·1680 (exp. 1) ·1672 (exp. 2)	·169 (*a*) ·169 (*b*)	·2675 ($19\frac{1}{2}^\circ$)	·272 (*a*) ·271 (*b*)
* Aluminium..80 Zinc 20	·1938 (exp. 1) ·1943 (exp. 2)	·193 (*a*) ·194 (*b*)	‡·3264 ($18\frac{1}{2}^\circ$)	·326 (*a*) ·328 (*b*)
* Aluminium..60 Zinc 40	†·170 (from five experiments)	·167 (*a*) ·169 (*b*)	§·288?	·277 (*a*) ·281 (*b*)
Aluminium..40 Zinc 60	Not determined	— —	·2349 ($21\frac{1}{2}^\circ$)	·242 (*a*) ·234 (*b*)
Aluminium..94 Bismuth 6	·2119 (exp. 1) ·2132 (exp. 2)	·208 (*a*) —	·3651 (21°)	·358 (*a*) —
Commercial Aluminium	·1913 (exp. 1) ·1922 (exp. 2)	·200 (*a*) —	·3282 ($14\frac{1}{2}^\circ$)	·338 (*a*) —

* Prepared from a casting by the British Aluminium Company.

† In this case the specific heat determinations were not in good agreement. Further observations are being made on certain peculiarities of the specimen which appear to be connected with this want of agreement.

‡ Determined after remelting and recasting the original specimen, which had minute blow-holes throughout its mass.

Internal cavities suspected.

It will be observed that the differences between the experimental and calculated values of the specific heats of the aluminium-copper and aluminium-zinc alloys are small and within the limits of experimental error.* As regards the specific volumes, the experimental values are in moderate agreement with the calculated. In the case of the aluminium-zinc alloys we should expect the mean specific volume of a complete casting to be nearly normal from the evidence of the fusibility-curves and microscopic examination, for these alloys, according to the classification of Le Chatelier,† belong to the same group as tin-bismuth, lead-antimony and lead-tin, all of which have normal or nearly normal specific volumes.‡ On the other hand, aluminium and copper give an abnormal fusibility curve,§ and, according to Guillet,|| form compounds (Cu_3Al, CuAl and $CuAl_2$) of markedly abnormal densities.¶

*For aluminium-copper compare a determination by Longuinine (*Ann. de Chim. et de Phys.*, 1882, Vol. 27, p. 407) of the specific heat of Al 11·3, Cu 88·7. Longuinine's values are ·10432 (found), ·1089 (calculated). The difference here seems larger than the experimental error, and it is worth noting that the composition is nearly that of Cu_3Al. In a recent memoir (again quoted in a subsequent note) Longuinine and Schukareff give the following values: ·1586 for $CuAl_3$ (approximately 44 per cent. Cu), ·1502 for Cu_4Al_9 (approximately 51 per cent. Cu). The calculated values (using the numbers for Al and Cu given in the present paper) are respectively ·164 and ·155, so that here also the observed are appreciably lower than the calculated values.

†*Metallographist*, 1898, Vol. 1, p. 95 (Charpy).

‡Maey, *loc. cit.*

§Le Verrier quoted by Roberts-Austen, *Metallographist*, 1898, Vol. 1, p. 346; Le Chatelier, *Annales des Mines*, 1897, Vol. 11, p. 201.

||*Science Abstracts*, 1903, No. 584.

¶ Compare Longuinine and Schukareff on the heats of formation of aluminium-zinc and aluminium-copper alloys, *Archives des Sciences*, 1902, Vol. 13, pp. 5-29, and 1903, Vol. 15, pp. 49-77. In the second of these memoirs the authors give the specific heats of Cu 44 per cent. and Cu 51 per cent. quoted in a previous note, and also values for the densities of these two alloys. The value for the density of Cu 44 per cent. shows a considerable contraction (about 6 per cent.), that for the density of Cu 51 per cent. no alteration of volume.

The last two alloys of the table show differences between the observed and calculated values both of specific heat and specific volume, but this may be due to experimental difficulties. The bismuth alloy was prepared by adding 10 parts of bismuth to 90 parts of aluminium; after four meltings the product seemed to be homogeneous,* but some of the bismuth had been removed in the successive examinations of the material. Mr. Race in two analyses of turnings from the outside of the specimen found 94·0 and 94·3 per cent of aluminium. It may be observed that, if the specific heat and specific volume are assumed to be normal, they would both correspond with slightly less than 97 per cent. of aluminium. As regards the specimen of commercial aluminium, the analyses and other indications suggested a want of homogeneity. The first analysis gave approximately aluminium 88 per cent., zinc 7 per cent., copper 4 per cent., lead 0·7 per cent., iron 0·4 per cent. Another analysis, using a relatively large quantity of the material, gave aluminium 84·8 per cent. After twice remelting and recasting the specimen, turnings from the upper end (outside) of the new casting gave aluminium 85·1 per cent., and turnings from the lower end (centre) gave aluminium 84·0 per cent. The calculated values of the table are on the basis aluminium 85 per cent. The observed specific heat, assumed normal, would correspond approximately with 79 per cent. of aluminium; the observed specific volume, assumed normal, would correspond approximately with 81 per cent. of aluminium.†

*According to Tissier Brothers, quoted by J. W. Richards, "Aluminium," second edition, p. 398, alloys containing up to 25 per cent. of bismuth may be made by mixing the metals.

†A second specimen of commercial aluminium (so called) gave similar results. Analysis made the percentage of aluminium 78, while both the specific heat and the specific volume (assumed normal) corresponded with a percentage 74½.

Manchester Memoirs, Vol. xlviii. (1904), *No.* 7.

VII. On Phenomena due to Repetitions of Stress, and on a New Testing Machine.

By FRANK FOSTER, B.Sc.

(Communicated by Dr. G. Wilson.)

Received and Read January 19th, 1904.

In this paper I wish to review some of the more important phenomena due to repetitions of stress on metals, to attempt to explain them and also to describe a new machine for their study.

The theory here sketched is mainly that presented by the author more than a year ago in a paper read before the Owens College Engineering Society*, but recent experiments by Professor Ewing whilst not affecting, indeed strengthening, the fundamental idea on which the theory rests have yet pointed out the existence of an important and at the time unforeseen development in the metal during alternations of stress.

About 40 years ago Wöhler showed that a bar of metal would ultimately break under a load less than its static breaking load as determined in the ordinary testing machine, provided that the load was removed and re-applied continuously. The number of these repetitions required to produce fracture was greater the less the stress, but fracture would ultimately result with loads which never by a large margin reached the elastic limit of the material.

Quite recently Professor Reynolds and Mr. Smith have shown also that the number of repetitions necessary for fracture is less the greater the rapidity with which they take place.

* "A possible explanation of the phenomena caused by repetitions of stress." *Mechanical Engineer*, Nov. 22nd and 29th, 1902.

Professor Ewing and Mr. Humfrey have shown that when a metal is subjected to an increasing stress in the ordinary manner there is no visible change in the crystalline grains of which the metal is composed until the elastic limit is passed and the extension has consequently become permanent. At this stage nearly straight lines (called by the experimenters, slip bands) appear on the surface of the grains, due to a slip or shear having taken place in the crystal along what is very nearly, but not quite, a plane surface. It is this slipping which accounts for the permanent extension of a metal stressed beyond its elastic limit.

In the account of his experiments on repeated stresses* Professor Ewing showed that when a metal was subjected to repetitions of stress less than the elastic limit of the material, after a time these lines or slip bands appeared on the crystals showing that in some way the metal has passed into the condition of a metal subjected to a statical stress greater than the elastic limit of the material; evidently as the repetitions continued the elastic extension became greater, each repetition adding something to the elastic extension until this extension was equal to the maximum elastic extension of the bar, after which any further repetitions of the stress would produce a permanent extension. According to the theory about to be sketched this increase in the extension is due to hysteresis in the metal. As the repetitions continued more of these slip bands appeared, showing more distortion of the metal until probably the distortion would have been sufficient to produce fracture, but this was prevented by a development which had not been foreseen in writing the paper for the Owens College Engineering Society,

* "Fracture of metals under repeated alternations of Stress." By J. A. Ewing and J. C. W. Humfrey. *Trans. Roy. Soc.* Vol. 200, Series A.

namely, some of the slips developed into cracks due it was thought to grinding between the adjacent surfaces of slip, for in these experiments—and it is important to note it—the cycle of stress was from zero to a positive maximum, then to an equal but negative maximum, and then back to zero; that is to say the loading was alternating in direction. The same remarks also apply to Professor Reynolds' experiments.

Now when a bar of metal is subject to a cycle of loading within the elastic limit (say from zero to a maximum tension and back to zero) at the end of the cycle it is found that there is still a slight extension or lag or hysteresis, which however disappears after a little time. This phenomenon is marked when long wires are rapidly unloaded. *Fig.* 1 is intended to illustrate this.

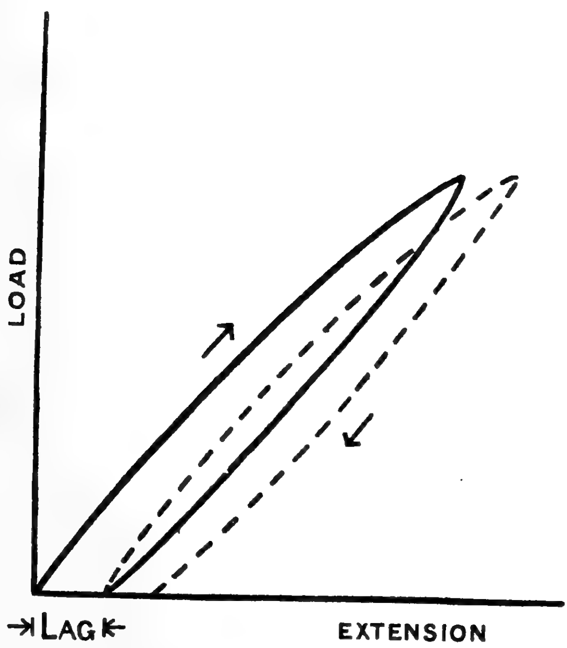


Fig. 1.

Evidently when the load is removed the extension begins to disappear at first very rapidly, then more and more slowly, somewhat as in *Fig.* 2.

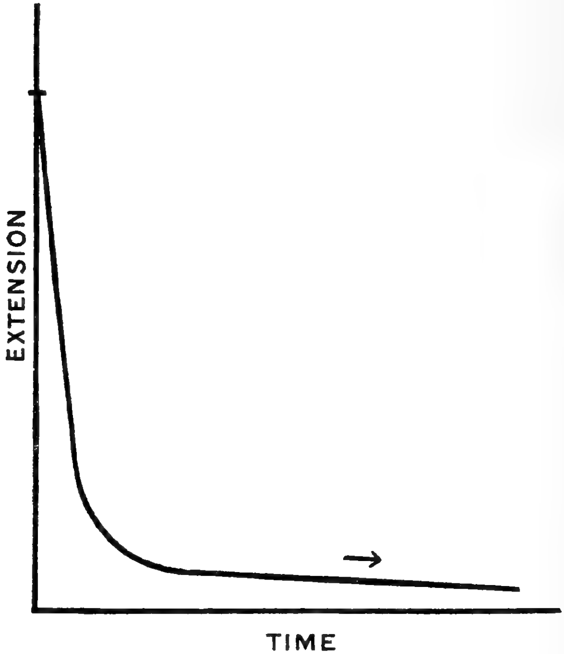


Fig. 2.

If now, before the bar has recovered, the cycle of loading is repeated we should expect the lag at the end of the second cycle (*Fig.* 1) to be greater than at the end of the first cycle (though probably less than twice the first), and so on until ultimately the total extension (which includes the total lag) is equal to the maximum elastic extension of the bar. At this point any further extension will be permanent and show itself by slipping along surfaces in the crystalline grains. Professor Ewing's results previously mentioned confirm this view.

If this were to go on the extension would increase until ultimately the bar would fracture, its shape changing as in a statical test.

Now slip surfaces produced in a crystal—especially since such surfaces are not quite plane and hence cannot fit or gear perfectly together—must be sources of weakness. If the load is removed there will be almost no reduction of extension it being practically wholly permanent, and hence there will be no—or very little—relative motion of the slip surfaces. If however the load is now reversed, that is applied in the opposite direction, the surfaces will slip over one another, and it appears that ultimately this grinding produces cracks which once started extend rapidly by tearing at their edges, and hence the special weakness of bars subjected to alternating stresses. This is illustrated in *Table* I. On the other hand the mere removal of the load should give rise to at the most only a little creeping of the surfaces due to the slight elastic extension always present, and hence we should hardly expect the cracks to form and the extension would proceed until finally the bar would break.

Unfortunately the bulk of experiments have been performed with alternating stresses yet even here considerable distortion of the specimen has frequently taken place. In general however under such conditions the specimen breaks along the cracks with a rough fracture.

In support of this view that probably with a unidirectional stress the cracks would not be formed or if formed would not be of great importance, we have the fact that for a given maximum stress the bar subject to alternations is immensely weaker than the bar subject to a unidirectional stress. (*Table* I.)

The results are not strictly comparable but the enormous difference in every case which is also borne out by the results of repeated torsions can hardly be due to the difference in the ranges of stress.

TABLE I.

Materials.	Simple Bending.		Bending : Rotating Bars.	
	Stress Limits.	Repetitions.	Stress Limits.	Repetitions
Iron for axles...	0, (+)15·28	[3,400,000]	(+)15·3, (−)15·3	56,430
Phœnix Co......	0, (+)14·3	[48,000,000]	(+)14·3, (−)14·3	99,000
Homogeneous Iron	0, (+)19·1	[34,500,000]	(+)18·2, (−)18·2	31,586

[ ] signifies not broken.
Stresses are in tons per square inch.

It may be thought that to effect a true comparison equal ranges of stress should be chosen. That this is not so is perhaps best shown by an illustrative example. Suppose the total elastic strain either (not total of both) in tension or compression to be $\frac{1}{90}$ inch, and the extension or compression due to a load of 8 tons is $\frac{1}{200}$ inch. Then for a stress range of either 0 to 8 tons or + 8 to − 8 tons the amount of lag or hysteresis required to give the bar a permanent extension is abont $\frac{11}{1800}$ inch. If however the unidirectional range of stress is made equal to that for the alternating stresses, that is 16 tons, the former will only have $\frac{1}{900}$ inch or $\frac{2}{11}$ that of the alternating stresses to make up in lag and it is practically certain that the difficulty of making up this lag increases very rapidly as its amount increases, for as pointed out earlier it is very unlikely—and experiment bears this out—that the lag of, let us say, loading cycle number 10,000 will be anything like as great as for the first cycle of loading. On the other hand it is not strictly fair to compare a range between 0 and 8 tons with a range between + 8 and – 8 tons as in the latter case the lag per cycle will probably be something less than twice that in the former. Hence if we doubled the repetitions of the alternating stresses we should obtain a fairer basis of comparison. But when all things have been considered it remains true that there is some special weakness induced by alternating as distinct from unidirectional stresses and hence the probability that the formation of cracks is at least not so serious in the latter case.

It may be wondered how the process of extension due to a lagging of the extension sketched in *Fig.* 1 is applicable to alternating stresses. *Figs.* 3 *and* 4 illustrate how it can occur. The change of stress from a positive

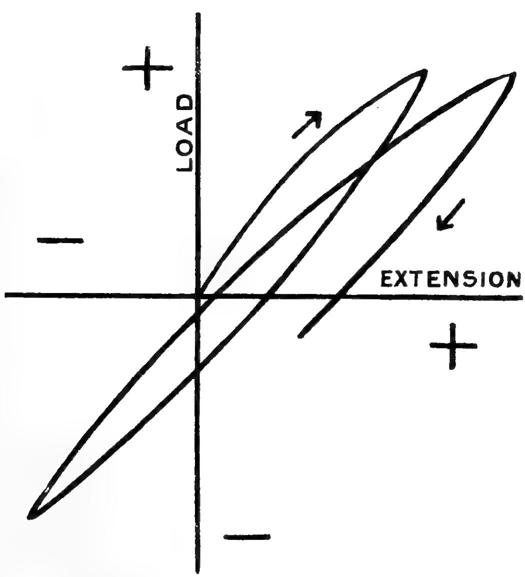


Fig. 3.

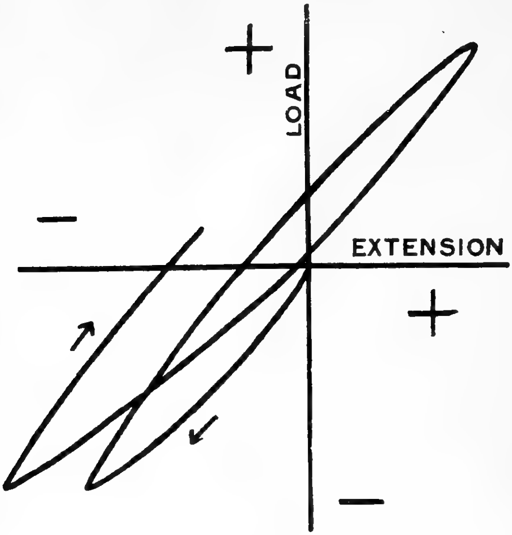


Fig. 4.

maximum to a negative maximum is continuous, and during such reversal the lag of the extension is continuously increasing, so that except just at the commencement of the loadings, which will in practice be applied in an indeterminate manner, the procedure is similar to that of a unidirectional stress and failure might result—apart from the formation of cracks—either by pulling out or crushing depending on the initial loadings. This is borne out by those specimens which have not failed by the formation of cracks.

Our theory leads us to several interesting conclusions. For instance, referring to *Fig.* 1, it is obvious that the greater the magnitude of the stress range the greater will be the lag per cycle and the less the total lag required, and hence the number of repetitions required to produce fracture will increase at an increasing rate as the stress range is decreased.

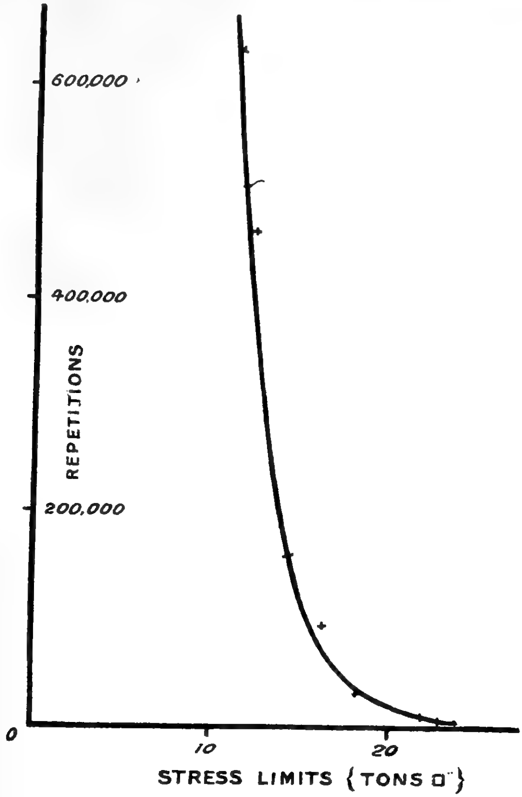


Fig. 5.

This is illustrated by *Fig.* 5 which shows the results of some of Wöhler's experiments. Wöhler in his conclusions drawn from his experiments stated that the number of repetitions required to produce fracture depended only on the magnitude of the stress range, and not at all on the positions of the limits of stress; that is to say it did not matter whether the stresses ranged between 0 and 10 tons or 10 and 20 tons. According to our theory the latter should indeed be much weaker than the former. Moreover, Wöhler's own results as given by Unwin are directly in opposition to his conclusion. *Table* II.

TABLE II.

Material.	No.	Stresses (tons per sq. in.) tension. Maxm.	Minm.	Mean.	Range.	Repetitions.
Homogeneous Iron	1	19·10	0	9·55	19·10	[34,500,000]
		33·41	14·31	23·86		1,234,600
		38·20	19·10	28·65		475,500
Krupp's Spring Steel, hardened.	2	28·65	0	14·3	28·65	[36,500,000]
		57·3	28·65	42·9		191,100
	3	33·4	0	16·7	33·4	300,000 (about)
		57·3	23·87	40·6		86,000
	4	38·2	0	19·1	38·2	339,150
		57·3	19·1	38·2		35,600
	5	42·95	0	21·5	42·95	200,100
		57·3	14·33	35·8	42·97	22,900
Krupp's Spring Steel *not* hardened.	6	23·87	0	11·9	23·87	[40,600,000]
		33·41	9·55	21·5	23·86	701,800
	7	28·65	0	14·3	28·65	468,000
		33·41	4·77	19·1	28·64	286,000
		38·20	9·55	23·9	28·65	176,300
		42·95	14·33	28·7	28·62	156,200
	8	33·40	0	16·7	33·40	197,400
		38·20	4·77	21·8	33·43	99,700
		42·95	9·55	26·2	33·40	81,200

[ ] signifies not broken.

gives all the results in Unwin's book (Unwin seems to support Wöhler on this point) bearing on this matter. It will be seen that in every case for a given range of stress that with the highest mean stress is the weakest. This is obviously of importance in engineering structures.

The influence of the rapidity with which the repetitions take place was discovered by Mr. Smith's experiments. The reason for it is obvious from *Fig.* 2. The more rapid the loading the greater is the lag, and this effect will moreover be most pronounced at high speeds. At very high speeds very few repetitions should suffice to produce fracture, whereas at very low speeds an enormous number should be necessary. This is quite borne out by Mr. Smith's results from which *Fig.* 6 has been prepared.

There are a number of other interesting points. Wöhler found for instance that sudden changes in the cross section of a specimen were very weakening. This is due to the more intense local stresses set up at the places of change. It is noticeable that even in Mr. Smith's specimens, where the changes of section were gradual, the specimen nearly always broke at these changes of section. This weakening is of course not so great for a steady load. In this case if the yield point at such a place is passed due to the local high stresses the result is merely to put the whole specimen into a state of relative ease.

Another interesting point is that according to Mr. Smith's experiments mild steel and cast tool steel (both annealed) are approximately equally strong under repetitions of stress (Wöhler's results are not so conclusive). This result may be due to the less time which the mild steel would occupy in passing through the elastic extension being made up for by the greater time which it would take to get through the permanent extension.

The question as to whether a metal can be restored after being subjected to a number of repetitions of stress requires further careful investigation. Ewing ("Strength of Materials," p. 56) states that "annealing in any case "serves to cure fatigue and restores the primitive quality "of the piece in respect of both strength and elasticity."

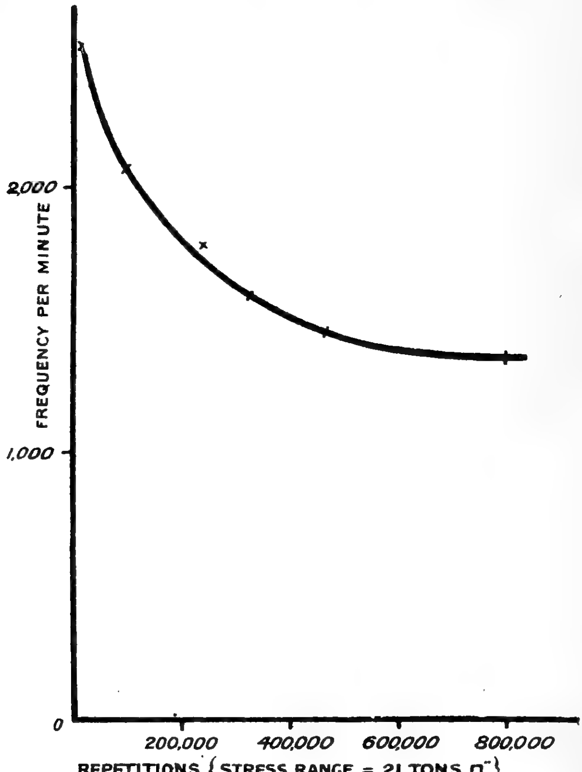


Fig. 6.

Mr. Smith states that his results on this point are however so discordant that they have not been published. Probably Ewing's statement is founded on practical experience, in which case probably the stresses would in many cases be unidirectional and generally not sufficiently often repeated to have brought the specimen very near the breaking point. Hence cracks would probably be non-existent or small in which case annealing would weld the grains together at the slip surfaces. If however serious cracks have been formed it seems unlikely that mere annealing without forging or some means of compressing the hot metal—a sudden cooling of the surface might do a little good—would do much in the way of restoring the metal, hence the discordant results of Mr. Smith's experiments.

Another very important point is that of the restoring effect, if any, of a period of rest. If no permanent extension has been reached then the lagging extension being elastic should disappear with a rest and the specimen would be as good as ever. In confirmation of this it is found that metal railway bridges subject to heavy traffic during the week-days sag a little but recover during Sunday's quiet. On the other hand if many slip bands have appeared, these being permanent not much can be expected from a period of rest except it be very prolonged or accompanied by gentle heating, say at 100° C., which has been shown to have a kind of slow annealing effect on metals. Even this would probably be absent in the case of a specimen which had bad cracks in it.

The raising of the elastic limit in tension by repetitions of tensile stress is evidently due to the permanent extension produced, and the consequent lowering of the elastic limit in compression is probably due to the looseness of the gearing between adjacent slip surfaces in the grains allowing a considerable inelastic motion to take place at reduced stresses (the forces of cohesion are supposed to vary inversely as the fifth or sixth power of the distance).

A New Testing Machine. Most experimentalists on repetitions of stress have adopted the simple method of rotating a bent bar. Unfortunately simple stresses cannot be obtained by this method. Professor Reynolds obtained simple alternating stresses by causing the specimen under test to reciprocate a dead weight in a straight path. The motion was obtained from a rotating crank shaft and was very nearly simple periodic. The stress producing mechanism was indeed essentially that of the ordinary steam engine. *The machine is illustrated diagrammatically

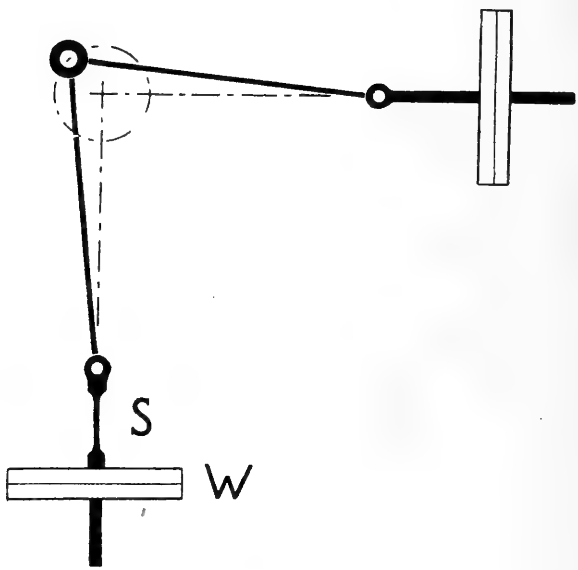


Fig. 7.

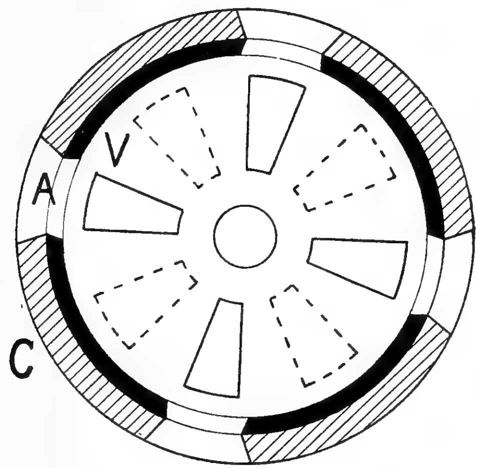
in *Fig.* 7. Two equal sets of parts at right angles to each other are driven from a single crank pin. The specimen is at *S*, and must transmit the forces required to accelerate and retard the weight *W*. In this way it is subject to

* "On a throw-testing machine for reversals of mean stress:" by Osborne Reynolds and J. H. Smith. *Trans. Roy. Soc.* Vol. 199, Series A.

approximately equal tensile and compressive stresses alternately. The horizontal set of parts is used merely to balance the vertical set and thus reduce vibration.

This machine is, however, limited in its rapidity of alternations to about 2,500 per minute, owing to mechanical and lubricating difficulties. Furthermore it can only give alternating stresses approximately equal in amount, and when running makes such a noise as to be a nuisance.

The machine about to be described is designed to get over these difficulties, and to possess other advantages to be described later.



Plan of Valve and Ports.
Fig. 8.

It consists (*Figs.* 8 & 9) of a piston *P* fitting into a cylinder *C*. Fixed in the cylinder is a transverse plate *S* with ports cut in it. Resting against this plate and rotating in the cylinder is the rotating valve *V* with ports in the transverse portion and a second set in the circumferential rim. The cylinder has a spacious steam chest *B* and admission ports *A*. The valve is driven at the required speed by the spindle *W*. As it rotates the rotary valve *V* first admits steam to the cylinder, then cuts it off and exhausts it through the plate *S*. In this way the piston *P* receives a succession of cycles of

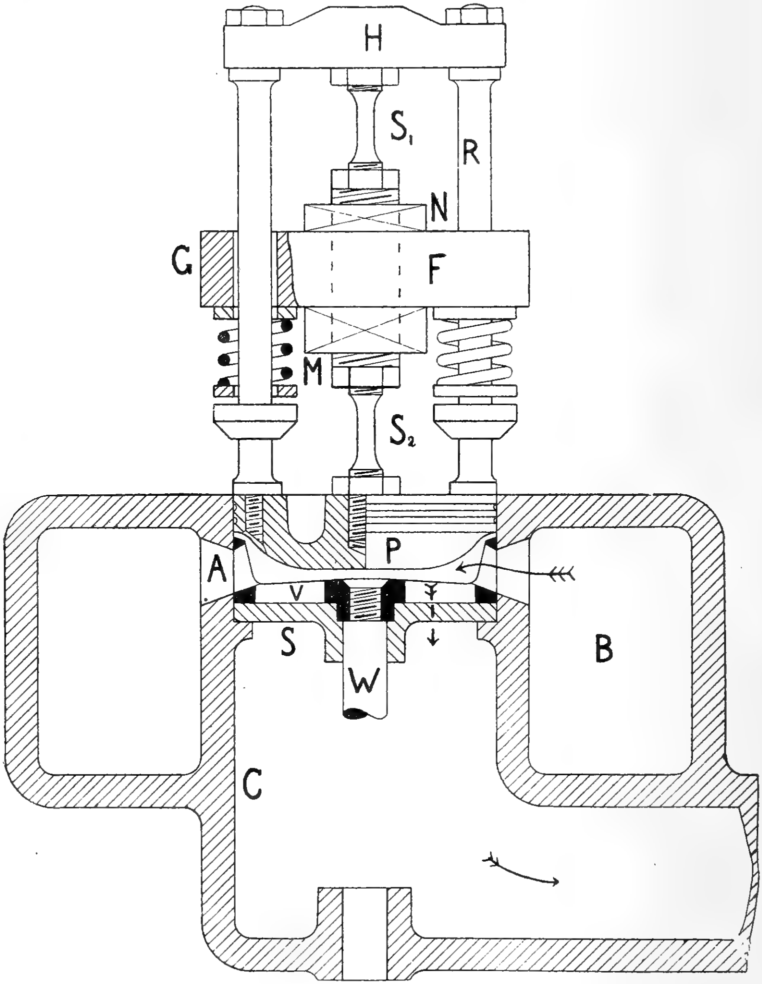


Fig. 9.

loading. Now if there are four complete sets of ports, *i.e.*, one complete set per quadrant, then four complete cycles of loading are performed per revolution, and hence it becomes very easy to get the highest frequencies of loading.

The specimen is fixed at S_2 between the piston and an arm of the frame F (one end being screwed into the piston, the other into a sleeve held in position relative to the frame F by locknuts M and N, which may, if necessary, be also small spur wheels for facility of adjustment) if for experiments under compression, or at S_1 between the crosshead H and the frame F if for tension. This crosshead H is connected to the piston by side rods provided with stops to limit the motion when the specimen breaks and running—preferably on roller bearings—in guides to prevent the piston jambing. A mark on a side rod will enable the experimenter to keep the piston in a constant position—if any adjustment is necessary—and thus ensure that the pressures attained in the cylinder shall not vary during an experiment.

In order to determine what pressures the piston is really subject to we may put indicators on the steam chest and exhaust space below S.

The lowest pressure registered by the former and the highest registered by the latter give us the limits of loading on the specimen. We may if we like put indicators on the piston itself. In this case, in order to secure correct readings, two separate springs should be used, the one for the upper and the other for the lower limit of pressure, and both springs should be restricted by stops to a small range of motion about that corresponding to the pressure to be measured. In this way most of the errors of the indicator would be eliminated. If it is desired to have the load-time curve a sine curve in order, as suggested by Dr. Lees, to get rid of any high frequency harmonics a first approximation to the shape of the ports can be made by calculation, but the final adjustment would have to be made by experiment. The forms so obtained would vary with the conditions of working.

It may be objected that,

First, the pressures in the cylinder will vary very little owing to the high frequency and consequent throttling of the steam,

and

Second, the pressures will not be applied steadily, that is, they will be equivalent to instantaneously applied loads.

The first objection is not very serious as it is easily possible to make the ratio of port area to cylinder volume large, and moreover there are no tortuous steam passages; also it should be remembered that in high speed engines, making, say, 1,000 strokes per minute, the clearance space amounting to about 20 per cent. of the working cylinder volume is filled with steam at the maximum pressure in a very small fraction of the stroke. There will, of course, be some throttling, especially just as the ports open, so that the pressure will not come on the piston instantaneously, that is, not more so than *any* load applied at such high frequencies would. Any dynamic action due to this high frequency of loading would be common to all methods of loading and therefore quite within the field of the research. If it is thought necessary the ports can be so shaped as to throttle the steam during the opening of the ports and gradually to increase the port opening to a maximum just before closing the ports. This would ensure a gradual change of load.

The limits of pressure can be varied by throttling the steam on admission to the steam chest and at exit from the exhaust spaces, and to keep these pressures constant the receivers should be large.

The machine could be made double-acting by providing it with two valves one on either side of the piston and thus alternating loads could be applied. A much simpler method would be to put a cylinder cover above the piston and keep the space between it and the piston at any constant desired pressure. In this way *any* limits of either tension or compression can be obtained.

The principal advantages of this machine are:

(1) There are no reciprocating parts, and hence no lubrication or inertia disturbances (in order to make sure that there are no appreciable inertia forces all the parts connected to the specimen should be made as light as possible consistent with ample strength).

(2) The highest frequencies of loading can be easily obtained.

(3) The lubrication is very simple.

(4) The frequency and loading can be varied independently of each other.

(5) Simple compression or simple tension between any limits can be obtained.

(6) Any limits of alternate tension and compression can be obtained by a slight modification of the machine.

(7) The specimen does not move and can therefore be kept under observation, microscopic or otherwise.

(8) The specimen can be made to carry an electric current or be placed in a magnetic field.

(9) The specimen can be enclosed in a temperature bath so that the effects of varying temperatures may be observed.

(10) The whole machine is very small and compact. Thus, with steam at 200 pounds per square inch, and a specimen a quarter of an inch in diameter, a five inch cylinder will enable stresses of 36 tons per square inch to be obtained.

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THE WILDE LECTURE.

VIII. The Evolution of Matter as revealed by the Radio-Active Elements.

By FREDERICK SODDY, M.A.

Delivered February 23rd, 1904.

Radio-activity may be defined as the property possessed by certain elements of emitting a peculiar kind of radiation continuously and without any external stimulus. A radiation is an influence transmitted through space radially from its source, and the first known example was of course that of light. Newton conceived the radiation of light to be due to the emission from the radiating object of tiny particles or corpuscles, which travel in straight lines through space radially in all directions. To-day we know that light is to be explained by the undulatory or wave motion of the luminiferous medium. The radiations from the radio-active elements, on the other hand, were at first thought to be waves, but are now recognised as the realisation of the Newtonian conception of light. That is, the radiations are caused by the radial flight of corpuscles or small particles, and each radiant particle carries with it an electric charge. The term "radiation" has therefore come to designate with equal propriety two fundamentally distinct phenomena. The past decade will probably be remembered for its discoveries of new kinds of radiations, and these have not been confined to the one variety. The "Radiant Matter" of Sir William Crookes, or to give the phenomenon the name by which it is now more generally known, the cathode-rays, produced by an

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electrical discharge in vacuo, have been shown to be due to the flight of rapidly moving corpuscles carrying a negative charge. The proof rests upon their property of being deviated by a magnet. As the conclusions of a series of researches which are quite beyond the scope of the present subject, Professor J. J. Thomson and his colleagues have shown (1) that the charge carried by the cathode-ray corpuscle is the atomic charge, or that carried by an univalent ion in electrolysis, (2) that the mass of the corpuscle is only about one-thousandth of the mass of the lightest atom known to chemists, (3) that the velocity of the cathode-ray corpuscle is ordinarily about one-tenth that of light, but varies within certain fairly wide limits. Lenard found that if a Crookes' tube is provided with a window of thin aluminium foil in the path of the cathode-rays, the latter are able to penetrate the window and can be investigated outside the tube. The corpuscles travelling with low velocity are stopped by the metal foil and those penetrating were found to possess velocities about one-third as great as that of light.

The X rays of Röntgen were the next discovery, and these, according to accepted doctrines, are new examples of ethereal waves. They result whenever the cathode-ray corpuscle suffers change of velocity, as for example, when it strikes an obstacle. A sudden electro-magnetic pulse is propagated in all directions from the corpuscle and gives rise to the X rays. These differ from ordinary light mainly in the irregular and sudden character of the individual pulses.

The rays we are most nearly concerned with were discovered by Becquerel in 1896, during an investigation of the fluorescence of certain compounds of uranium. We know now that the new radiation is not connected with fluorescence, but is a specific and unalterable property of the element uranium and of certain others. An insignificant proportion of the radiation, the so-called γ rays, resembles the type discovered by Röntgen, and are probably X rays of very great penetrating power, which result at the moment of the expulsion of the β rays. The latter have been shown by Becquerel to consist of very high-velocity cathode-rays, and Kaufmann has detected in the radiations of radium cathode-rays travelling with a speed of 95 per cent. of that of light. But although experimentally very obvious the β rays are, like the γ rays, of secondary importance. The fundamentally new feature in the phenomenon of radio-activity is the type of radiation known as the α rays. Rutherford* last year proved that these, like the β rays, were deviated by a magnetic field, but in the opposite direction, indicating that the α particle is positively charged. The deviation is extremely small, even in the most intense magnetic field it is possible to obtain, and the radius of curvature of the ray in a field of given strength is about a thousand times greater for the α ray than for the cathode-ray. If we accept the view that the charge on the α particle is the atomic or ionic charge, Rutherford showed by measuring the extent of the deviation that its mass is of the same order as that of the hydrogen atom, and its velocity is about one-tenth of that of light. Thus the radio-active substances spontaneously expel into space particles of atomic dimensions with a velocity of twenty thousand miles a second.

The foregoing is a brief review of our knowledge with regard to the new kinds of radiation. We have seen that the X rays and probably the γ rays are ether disturbances, while the cathode-rays, and the α and β rays are corpuscular in character. Yet the resemblance of the two

* *Phil. Mag.*, 1903, s.6, v.5, p. 177.

classes to one another is extremely close, and it is only in the action of the magnetic field that the difference is apparent. Thus, as a first approximation, the different types of radiation penetrate matter in proportion to its density, and independently of its nature. If layers of equal area and equal weight of the various different kinds of matter are compared, the stopping power will be found similar for each. The phenomenon exhibited by light of being able to pass without much loss through great thicknesses of certain kinds of matter known as transparent, and of being stopped completely by the thinnest sheets of other kinds, is unknown for the new types of radiation. The penetrating power of the latter varies very widely for the different types, the γ rays being able to pass with ease through an inch of steel, while the α rays are completely stopped by a sheet of notepaper. But the law that the absorption of the radiation is proportional to the density of the matter traversed, holds approximately for each of the new types.

The methods used in the detection and investigation are the same for all the radiations mentioned. All are invisible to the unaided eye, but possess the power of causing certain fluorescent substances placed in their path to emit visible light, or to fluoresce, although this power varies widely with the different substances under the influence of the different kinds of radiation. All the new radiations affect the photographic plate in the same way as light, although again in very different degrees. Their most important property is their power of ionising the air or other gases through which they pass. Under these conditions the gases are for the time being made capable of conducting electricity in amounts proportional to the intensity of the radiation.

The three properties last mentioned furnish the experimental means employed in the detection of the new invisible radiations. The last, which expresses the intensity of the rays directly in terms of an easily measured electrical quantity, has been developed by Rutherford into an extremely accurate and convenient method for the qualitative and quantitative study of the property of radio-activity.

It is a matter of remark how nearly the corpuscular forms of radiation resemble the undulatory variety, as exampled by the X ray. It furnishes a remarkable vindication of the insight of Newton into natural phenomena, that, when the process he imagined light to be was discovered three centuries after, it should have been first taken for a different variety of light vibration. The *α* rays of the corpuscular class can only be differentiated from the X rays of the wave class by the application of the most powerful agencies and by the aid of the most refined measurements the present century can command.

Two years after the original discovery of radio-activity in uranium, it was shown that the element thorium possessed the same property to about the same degree. In the same year Mme. Curie satisfied herself that these two of all the known elements possessed the property, but was led to suspect the existence of a new and powerful radio-active element in the mineral pitchblende. The latter often contains 80 per cent. of uranium oxide, but it is several times more radio-active than either uranium or thorium oxide in the pure state. After many years' work in conjunction with M. Curie and M. Bemont, in which the radio-activity furnished the necessary means of tracing the new element, a minute amount of the latter in the form of chloride was separated from pitchblende in the pure state, and given the name radium. The proportion in which it exists in the mineral is probably less than one part in a million, and many tons of the ore had to be worked up before enough of the new element was obtained for investigation. The radio-activity on the other hand is enormous, being at least a million times greater than that of either uranium or thorium. Mme. Curie also obtained evidence of the existence of another new element, which she named polonium, and Debierne of a third, actinium, both present in pitchblende in such minute quantity that their isolation as specific substances has not yet been effected. Radium however has been obtained in sufficient quantity for its atomic weight and spectrum reaction to be determined, and these leave no doubt whatever of its elementary nature. Its atomic weight, as determined by Mme. Curie, is 225, while that of thorium is 232, and of uranium 238, and these three are the highest known. Radio-activity is thus the property of the three heaviest types of atoms at present recognised.

The reason why it is necessary to consider that polonium and actinium are new elements, although neither has yet been isolated, is a point of some fundamental importance. Radio-activity is a property of the atom of the element in question which cannot be modified in extent or altered in quality by any known means. It can be detected, by the aid of the electrical method, with quantities of the element far smaller than can be directly recognised. In the case of radium, although its spectrum reaction is one of the most characteristic and easily detected, a quantity of the order of a million times less than the spectroscope would recognise, can be readily distinguished by its radio-activity. The nature of the radio-activity of any one element is not only an unalterable property of the element, but can readily be employed to distinguish and differentiate it from other elements possessing the property. It is not possible, for example, that the activity of uranium can be due to a trace of admixed radium. Polonium is distinguished from all the other types by the fact that its radiation is entirely of the α or non-penetrating kind. Actinium is distinguished by a characteristic emanation, which loses its activity much more rapidly than those produced by either thorium or radium. The cases considered constitute at least five specific examples of radio-activity, and these require the existence of a similar number of radio-elements. It is interesting to note that this conclusion is arrived at without appeal to a single chemical property of the matter in question. A new radio-element may be recognised by the means indicated, even when enough of the substance has never been obtained either for its atomic weight, spectrum reaction, or any chemical property to be determined. Knowledge with respect to these properties will follow, as in the case of radium, when a sufficient quantity is accumulated. But this sufficiency may be of the order of a billion times greater than that required for a complete examination of its radio-active properties.

The five elements considered differ enormously in the extent of their radio-activity. Uranium and thorium are so feebly active that they had been studied in the past for something like a century before their radio-activity was discovered. Radium was suspected on account of its powerful activity, and for a long time in the early stages of the search this was the sole evidence of its existence, while with actinium and polonium our knowledge has not yet advanced beyond this stage. But the general character of the α radiations emitted is similar for each case, and all but polonium emit β and probably γ rays also. Although the characteristics of any one type of radiation vary somewhat in the different elements, the differences are not great. It will be seen at once that the only explanation, on the discrete theory of the rays, of the different degrees of radio-activity exhibited by the various radio-elements is that a different number of particles are expelled from unit weight of the substance in unit time. The general character of the α particles expelled is similar in the case of each of the radio-elements. Rutherford was the first to recognise the preponderating importance of the α radiation in the phenomenon of radio-activity. He showed that in all cases they probably represent over 99 per cent. of the energy radiated, so that the energy radiated by the β and γ rays together is a very small fraction of the whole. We now know that the β and γ rays are secondary phenomena in point of time. The expulsion of the α particle starts the process and the expulsion of the β, and the emission of the γ ray which accompanies it, occur much later on as the process nears completion.

A theory accounting for the cause and nature of radio-activity was put forward by Professor Rutherford and myself, as the result of an investigation of the radio-activity of thorium, before the discrete nature of the α radiation was known. For the sake of convenience the complete theory[1] in its present state will be here considered, without reference to the historical order in which the steps were evolved. The elements exhibiting radio-activity are regarded as undergoing a slow spontaneous transformation into other elements. The change is slow only with regard to the mass of the material, an extremely minute fraction of the total undergoing change in the unit of time. But for the individual atoms changing, the transformation is sudden, and of the nature of a disintegration or disruption. The α particles are small fragments of the disintegrating

[1] *Phil. Mag.*, 1902, s.6, v.4, pp., 370 and 569; 1903, s.6, v.5, pp., 441, 445, 561 and 576.

atoms projected radially into space with terrific energy. The flight of these particles gives rise to the α radiation, their stoppage to all the well-known effects by which the rays may be recognised. Thus fluorescence is produced when the particles strike an obstacle capable of vibrating with such a period as to produce light waves. The ionisation of gases is brought about by the collisions of the α particles with the neutral molecules of the gas, whereby the latter are torn apart or dissociated into oppositely charged particles or 'ions.' Most generally and with any obstacle the energy of the α particles is converted into heat. This was shown experimentally last year by MM. Curie and Laborde, who proved that a solid radium preparation maintains itself some degrees hotter than its surroundings. As we have seen the α rays are stopped with great ease, being completely absorbed by one thickness of paper, and as they are produced equally throughout the mass of the radio-active substance, this result is to be expected. The radium gets hot through the incessant bombardment to which it is subjected by its own α radiations, in the same way as a target would get hot if placed in the line of fire of a Maxim gun. The real question of course is as to how the α particle gets its enormous energy in the first place.

Atomic disintegration would have been a difficult process to establish by direct experiment as the cause of radio-activity, had the phenomenon not been somewhat complex. The complexity of radio-activity, especially in the case of the element thorium, made it possible that so far-reaching a conception as the one put forward should be subjected to rigorous experimental verification. The process of disintegration is analogous in form, at least so far as the individual atom is concerned, to the sudden disruption of the molecule of an explosive substance like acetylene, fulminate of mercury, etc. The difference appears when we consider the whole mass of the substance instead of the individual particle. For the case of an explosive compound, the disruption of a single particle causes the surrounding particles to disrupt, and the whole compound explodes in an excessively short space of time. In the case of a radio-active element, a fixed and small proportion of the total disintegrates in the unit of time, without affecting the rate of disintegration of the remainder. This disintegration process proceeds according to this law for each type of unstable atom known. The rate, or proportion of the total breaking up in the unit of time, varies enormously in the different types, but is for any one type fixed and independent of the most powerful chemical and physical agencies to which the substance may be subjected. If, however, the disintegrating atom passed from its initial to its final state in one change, as in the analogous molecular cases considered, it would have been difficult to have obtained much knowledge of the process. Fortunately this is not the case. The thorium atom passes to its final state after at least five separate and successive disintegrations, each of which, considered by itself, is suddenly and explosively consummated so far as the individual atom is concerned, by the radial expulsion of fragments in the form of α particles. In the case of radium the number of disintegrations suffered by each atom is probably similar to the case considered, while in the case of uranium only two stages are at present known.

The complete series of changes of the disintegrating atom therefore takes a considerable time for completion. In consequence there exist a certain number of short-lived transition-forms of matter intermediate between the initial and the final atoms which result from the process. The term "Metabolon" has been proposed by Professor

Rutherford and myself to denote unstable atoms of this character, and the name indicates the essential feature which characterises them, and the means employed in their investigation. A metabolon is an atom with a limited life. While it exists it is a normal atom, possessing the ordinary attributes of matter. At the moment of its disruptive change it exhibits the property of radio-activity.

An obvious criticism may be anticipated. It may be objected that the word atom means 'indivisible,' and that a disintegrating atom is a verbal absurdity; the argument being that if the particle does change it *ipso facto* cannot be an atom. This argument, of course, involves the assumption that an unchangeable thing is also necessarily unchanging. The weather, for example, is unchangeable in the same sense as the atom is, for both have defied our active efforts to change them. The line must be sharply drawn between personal inability and natural impossibility. So far as the former is concerned, the metabolon accords with the experience of chemistry with regard to the atoms. It changes, but we are powerless either to stop it changing or to affect its rate of change. The cause of the change is beyond our control.

The above view of radio-activity explains at once what may be termed the dual character of radio-active matter, according as its ordinary material properties or its radio-active properties are under consideration. There is nothing abnormal in the chemistry of uranium or thorium which can be connected with their radio-activity. Radium from its atomic weight, spectrum reaction and chemical behaviour is a completely normal heavy element of the alkaline-earth family. The recent examination of its spectrum by Runge and Precht has revealed in a remarkable way how closely radium resembles barium, strontium, and calcium. Between the three radio-elements there is no chemical resemblance, and heavy atomic mass is their sole common characteristic. These facts bear out a view for which we shall find abundant additional evidence as we proceed that the life of an atom, and therefore the degree of radio-activity the corresponding element exhibits, is not connected with its chemical properties. It is not even connected with the atomic mass in the sense that the greater the latter is the more unstable will the atom be. Situated as we are, the observers for a short time only of a process of evolution which has been going on for indefinite ages, our knowledge of the unstable atoms is necessarily limited by certain definite considerations. These will be more fully considered in the sequel. Of all possible groupings of the 'protyle,' the atoms of the periodic law probably represent only a selected number, viz., the forms with longest life, which exist to-day because they have survived a long process of evolution in which those physically unfit have disappeared. The transition-forms already spoken of represent on the other hand the elementary forms of matter physically unfitted to survive, but which are brought within our powers of knowledge because they constitute the temporary halting places through which matter is passing in a scheme of slow continuous evolution from the heavier to the lighter forms. The original radio-active elements may be described as the connecting links between the two classes, partaking of the properties of each. They are changing, but so excessively slowly that some still survive. The point that must be made clear here is that, so far as we know, the life of an atom and its material properties are not connected in any obvious way. This is brought out by a study of the transition-forms. During the whole existence of the metabolon, whether it is long or short, it behaves like an ordinary atom. No indication whatever seems to be given of its approaching end, but suddenly by some internal cataclysm, the cause of which is at present almost beyond conjecture, it flies into pieces and so ceases to exist as such. Radio-activity is a property contributed by a few atoms only in any given instant. The vast majority are for the time being ordinary inactive atoms with a specific and characteristic material nature which is not affected by, or does not exert any influence on, the character of the additional set of properties contributed by the fraction disintegrating. For many purposes however a property which is contributed by a *constant* fraction of the total is indistinguishable from a property possessed by each atom in common. Thus Mme. Curie in her earlier researches described each atom of a radio-active body as behaving as a constant source of energy. The discovery of the transition-forms has shown otherwise. The question at issue between the two views is in reality nothing short of a question between a discrete and a continuous structure of matter. The whole phenomena of radio-activity would be an absolute enigma on the latter view. A step-by-step change in which there is a sudden break in properties at each step, and yet which proceeds gradually in the mass of the matter, demands an atomic hypothesis, and the radial expulsion of matter into space is only intelligible if the projected manner is in the form of discrete particles. These are generalities. The facts of radio-activity throw new light on the nature of these atoms, the effect having been to confirm in a most remarkable manner the theory first propounded by Dalton to this Society one hundred years ago. We know more about the atoms to-day than Dalton did. From the very immensity of the phenomena which attend its birth and destruction we know that under ordinary circumstances, as for example in the whole sphere of chemistry, the atom is the true unit of change. At the same time a new world has been opened to us by the discovery of radio-activity, in which the atom is not the unit, in which the forces are not chemical, and in which common physical conceptions such as temperature are without meaning. The further we advance into this sub-atomic world we realise how completely it is removed from the plane of molecular and atomic considerations. We can watch, it is true only as spectators without power to interfere, the progress of sub-atomic change, and from the novel character of the phenomena manifested, it is clear that the atom of Dalton represents a very real and distinct stage in the complexity of matter which under all ordinary circumstances is conserved. The fundamental theory on which Dalton founded modern chemistry may be said to have received a positive proof by the discovery of the nature of sub-atomic change.

In the papers by Professor Rutherford and myself already alluded to it was our object to show that the facts of radio-activity led without possible alternative to the theory of atomic disintegration. Here a less rigorous treatment of the problem must suffice, and the argument will be inverted. The possibility of atomic disintegration on the lines laid down will be assumed, and the phenomena of radio-activity shown to follow as simple and natural consequences. In the first place, since the process is not affected by any known agency, we must assume that it has proceeded continuously during past ages at the same rate, for any given type of matter, as it is proceeding at present. Hence it follows that the initial process of disintegration must be excessively slow, in order that some of the matter disintegrating should survive to the present day. The initial type of matter will be termed the parent-element. For any ordinary quantity of parent-element, considered over any ordinary period of time, the actual quantity of the transition-forms of matter resulting from the disintegration must be excessively minute. The quantity of the transition-form produced, moreover, cannot accumulate beyond a certain limiting or equilibrium value, which is attained when the amount changing per second equals the amount produced per second. This condition will be termed radio-active equilibrium. Since the rate of production is slow, and the rate of change of the transition-form is rapid, the equilibrium quantity must always be practically infinitesimal, and quite below that needed for detection by ordinary methods. But the rapid rate of change of the transition-form and the expulsion of α particles which accompanies the change, afford the means whereby these transition-forms can readily be detected and studied, although only present in so small quantity that no other evidence of their existence is manifested.

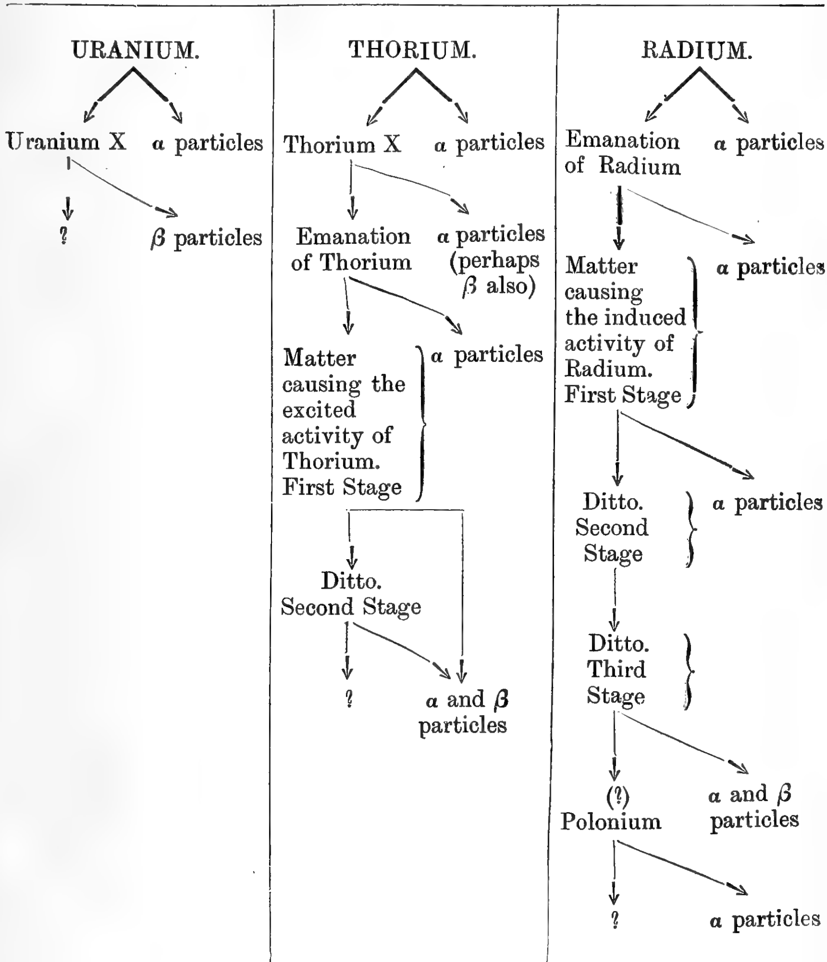
Looked at in the broadest and most general way the sole criterion which determines whether a transition-form can be detected experimentally or not is whether the energy liberated from unit weight in unit time is sufficiently great, and is manifested in a suitable manner to be detected by our instruments. That the energy liberated in the disruption of the atom is enormous is sufficiently shown by the fact that a gram of radium can liberate 100 calories per hour, year after year, without the supply showing appreciable signs of diminution. We have seen that a quantity of radium a million times less than can be spectroscopically detected can be recognised by its radio-activity, *i.e.*, by its energy-emission. If this energy-emission, instead of being spread over a term of centuries as it undoubtedly is in the case of radium, went to completion in a period of time varying from a few weeks to a few seconds, as in the case of the best known metabolons, it follows that the energy-emission in unit time would be correspondingly greater, and that a proportionately smaller quantity would come within the range of experimental detection. The quantities of the recently discovered transition-forms thus brought within our powers of knowledge are more appropriately expressed in multiples of the number of atoms, than in grams or similar measure. The energy of a single α particle can be calculated from its mass and velocity, and shown to be between 10^{-5} and 10^{-6} erg, and this is certainly not greatly below the limit of detection by the electrical method. Indeed it is still open to question whether the scintillations discovered by Sir William Crookes[1] in the phosphorescence of zinc sulphide exposed to the α rays of radium are not caused by the several impacts of the individual particles,—that we are not in fact witnessing the effects of single atoms of matter.

In the accompanying table the course of the disintegration of the three best studied radio-elements is given so far as it has yet been experimentally traced.

It will be noticed that the resources of the nomenclature available hardly stand the strain of providing names for the numerous transition-forms now known. Rutherford has recently suggested the term "Emanation X" for the matter causing the 'excited' or 'induced' activity of radium and thorium. No detailed account can be here given of the various new bodies, or the manner in which they have been separated from the parent-elements. In these separations one relies on the ordinary material

[1] The same phenomenon was independently discovered by Elster and Geitel for the radio-active matter obtained from the atmosphere.

Table of the known Disintegration Series.



nature of the bodies, and certain of the ordinary methods of chemical analysis prove sufficient for the task. The emanations and their subsequent products of change have been the most studied, owing to the former being gaseous, and so continually separating themselves by diffusion (emanation) from the parent-elements producing them. The fact that the emanations condense at the temperature of liquid air affords the means whereby they can be freed entirely from other gaseous matter present, and as we shall consider later, has resulted, in the case of the emanation of radium, in some important additions to our knowledge.

All the transition-forms have the same general characteristics. We have seen that they can only attain infinitesimal quantity, and are known by their rapid rate of change. It follows in consequence that their energy is quickly dissipated ; the radio-activity continually decays to zero in a geometrical progression with the time ; and the rate of decay furnishes a measure of the rate of change, and is a constant characteristic for each type of matter concerned. Under ordinary circumstances the radiations from a radio-element which has attained the condition of radio-active equilibrium are contributed for the most part by the various transition-forms which result from its disintegration, and only a small part is derived from the initial disintegration of the element itself. But this part cannot be separated by chemical means, because nothing can stop a certain fraction of the total number of atoms of the parent-element disintegrating per second. This is the "non-separable radio-activity." Since the fraction of the parent-element disintegrating is infinitesimal, the total amount does not perceptibly diminish. The non-separable activity is therefore sensibly constant even over long periods of time.

The operation of separating the transition-forms from the parent-element by chemical means does not in any way affect the course of the disintegration. Left to itself the parent-element steadily accumulates a fresh crop of the transition-forms separated, while the quantities originally separated disappear as such by further change. As the activity of the parent-element recovers to its maximum or equilibrium value, that of the transition-forms decays to zero, and the sum total is always the same as if the separation had not been effected.

Radio-activity, as the manifestation of atomic disintegration, has thus introduced us to a whole series of new unstable elements which at present find no place in the periodic table, and of which, except in the single case of radium, we possess but little chemical knowledge. They are the products of a material evolution, the initial stage of which is so slow that the ages that have elapsed since it started have not yet sufficed for its completion. But after the initial stage is passed the evolution proceeds rapidly, and passes from stage to stage so quickly that almost all we know at present of the intermediate forms is derived from the energy-phenomena which mark their appearance and destruction. Yet these phenomena, viz., the expulsion of rays, are so characteristic and so fitted for exact study that our knowledge is by no means necessarily scanty, although it is of a kind not usually associated with ordinary matter. We are in a new science, and its correlation to other sciences must be held secondary to its own development. This appears at once when the means of identifying and distinguishing the different types of metabolons from one another are compared with those employed in the case of the stable atoms. For the latter, atomic weight, spectrum reaction, and general chemical and physical nature are the distinctive criteria employed. In the case of the metabolons, physical and chemical nature can sometimes be fairly completely studied. For example, the emanations have been found to possess that curious power of resisting absorption by chemical reagents which associates them in nature with the inert gases of the argon family. They might be identified, moreover, by their temperature of volatilisation and condensation, or by their rates of diffusion. But these are somewhat special cases. The most valuable criterion which is universally applicable is the rate of change, and since the universal law is that a definite fraction changes in the unit of time, the rate of change is expressed by λ, 'the radio-active constant' which represents the proportionate fraction changing per second. Thus the emanations of radium and thorium are very similar in their general characteristics, but are widely different in their rates of change. λ for the case of the thorium emanation is about 1/87, while for the radium emanation it is 6,000 times smaller. The radio-active constant is determined by the rate of decay of the activity of the transition-form. The number of α rays expelled per second, *i.e.*, the radio-activity, is a measure of the number of metabolons changing per second, and therefore, since a fixed fraction changes per second, of the number remaining unchanged. The activity decays in a geometrical progression with the lapse of time, and the quantity diminishes accordingly. If I_0 is the original activity, and I_t the activity after time t, the value of λ is given by the equation—

$$\frac{I_t}{I_0} = e^{-\lambda t} \quad \text{or} \quad \log_e \frac{I_t}{I_0} = -\lambda t.$$

Thus the value of $\frac{I_t}{I_0} = \frac{1}{2}$, *i.e.*, the quantity is diminished to half the initial, in about one minute in the case of the thorium emanation, and in about four days in the case of the radium emanation.

A relation perhaps more generally useful than the radio-active constant is its reciprocal $1/\lambda$, which has a very interesting physical significance. It represents the *average life* of the metabolon in seconds, and affords a more concrete mental picture than the rate of change. Thus for the thorium emanation the average life of the metabolon is 87 seconds, for the radium emanation 5·8 days. The average life of a metabolon may be compared with the atomic weight in the case of a stable atom as a constant well suited for its experimental identification. It may be pointed out that the actual life of the different atoms of the same unstable element has all values between zero and infinity. Some break up during the first second of existence, and since only a fraction of the total changes per second, the quantity is, theoretically, never reduced to zero, and some persist indefinitely. This constitutes the first difference in properties between the individual atoms of the same element that has ever been discovered. It may be likened to the individual differences of velocity that exist between the molecules of a gas at constant temperature according to the kinetic theory. It is open to question whether all atomic properties are not really average properties, the individual atoms continually passing with great rapidity through phases varying widely among themselves in chemical and physical nature.

In the following table the average lives of the best known metabolons are arranged in order, together with the average lives of the atoms of the so-called permanent radio-elements. The latter will be again referred to.

Name.	*Average Life,* $1/\lambda$
Actinium Emanation ...	5·7 seconds
Thorium Emanation ...	87 seconds.
Radium "Induced Activity Matter" (last stage) (Emanation X) ...	43 minutes
Thorium "Excited Activity Matter" (last stage) ...	16 hours.
Radium Emanation... ...	5 days 8 hours.
Thorium X	5 days 19 hours.
Polonium	About 16 months (?)
Actinium	?
Radium	About 1,500 years.
Thorium, Uranium	About 1,000,000,000 years.

All the recent advances that have been made in our knowledge of the ultimate constitution of matter have a common starting point. The energy associated with matter under special circumstances has been the object of study, rather than the matter itself by direct means. In consequence, far smaller quantities than could be directly perceived have been brought within the experimental range. Thus in the phenomenon of a conducting gas, the 'ion' or charged atom is rendered evident by means of its charge and differentiated from the rest of the gas, although its quantity even under favourable conditions is probably less than one-billionth part of the whole. In consequence, as Professor J. J. Thomson has remarked, we know far more about the ion than we do about the uncharged molecule. Again, if the ion is placed under the influence of sufficiently powerful electrical attraction or repulsion it may acquire kinetic energy to such an extent that its existence may be thereby revealed even in such minute quantity that the detection of the charge carried would be an experimental impossibility. This is the case with the negative ion when under the conditions stated it becomes a cathode-ray particle. In the disintegration of the metabolons we have ions, or positively and negatively charged particles, shot out as rays spontaneously with speeds far exceeding any that can be produced by the action of electrical forces, and as we have seen, we have arrived at such a point of refinement, that it would seem that further advance must be stopped by our reaching the limit of the subdivision of matter. But deprive an ion of its charge, the radiant particle of its kinetic energy, or the metabolon of its power to further disintegrate, and they pass at once beyond our ken. The matter remains, but the energy is lost, and we must fall back upon direct methods, the use of the spectroscope, or the employment of chemical tests, and these even if they were a billion times more sensitive than they are would by no means suffice for the purpose.

This difficulty attended the important question as to what are the ultimate products remaining when the successive distintegrations of a radio-element have run their course, and the matter has again reached a stable state. There are two ways in which the problem may be approached. Either the time over which the products of the disintegration are allowed to accumulate may be sufficiently extended, or the quantity of material employed may be correspondingly increased. The first method was the more immediately applicable. For in the natural minerals which contain the radio-elements it must be supposed that the products of the disintegration have been steadily accumulating throughout past ages, and should be present in sufficient quantity to be detected by ordinary means. This led

Professor Rutherford and myself to suppose that possibly *helium* was such a product. The evidence was of course indirect, but very suggestive. Sir William Ramsay in 1895 discovered helium for the first time in terrestrial sources, as a constituent of certain minerals, and drew attention to the fact that it was only found in those minerals which contained uranium and thorium. Many of these we now know contain radium also, so that it may be stated that helium only occurs in minerals which contain the radio-elements. The study of the chemical nature of helium showed that it was a gas, like argon, belonging to a chemically inert family of elements, none of which up to the present time have ever been made to enter into chemical combination. Moreover, helium of all the known gases is the only one that has never been liquefied, and the origin of its occurrence in the uranium and thorium minerals, pent up or 'occluded' in a curious and unexplained way, remained a complete mystery. It may be released from the mineral by heat or solution, but once liberated cannot be re-absorbed. In the work by Professor Rutherford and myself on the radio-active emanations of radium and thorium it has been noticed that these gases, which also resemble argon in their chemical inertness, frequently do not escape from the dry solid radium and thorium compounds producing them, but remain stored up or 'occluded,' much in the same way as the helium in minerals, being liberated by heat or solution. It seemed likely that the explanation in both cases was the same. The gases being formed throughout the bulk of the substance, under favourable conditions remain mechanically imprisoned within it. On this view helium represents the accumulations during past epochs of one of the final products of change of one of the disintegrating elements present in the mineral.

The discovery of radium by Mme. Curie, and its preparation on a commercial scale by Herr Giesel, afforded the opportunity of putting the view to direct experimental test. The activity of radium is of the order of a million-fold greater than that of uranium or thorium, and the element must therefore be disintegrating a million times more rapidly. Radium, as will be deduced later, is itself probably of the nature of a slow-changing transition-form, which results from the disintegration of one of the heavier elements present in pitchblende, and the philosophical way of regarding the research, is to consider the radium employed as representing the equivalent quantity of mineral. Thus the quantity of material investigated could be made very large and the second of the two possible methods described became available. The experiments were carried out last summer by Sir William Ramsay and myself. Although the quantities of radium we were able to employ were only small, viz.,in two succeeding experiments, 20 and 30 milligrams respectively, they each represent the essential portion of at least a hundred kilograms of the original mineral. At the time of making the experiments they had been allowed to remain some months in the dry solid state, and it was assumed for the reason mentioned that the helium produced during that time would accumulate in the solid and be liberated when it was dissolved. The gases obtained in this manner were freed from the hydrogen and oxygen which are always present, through the decomposition of the water of crystallisation which occurs (Giesel), by means of a glowing spiral of partially oxidised copper wire. They were then forced through a capillary U-tube immersed in liquid air to condense the emanation and any carbon dioxide present, into a spectrum tube of excessively small volume. Practically the complete spectrum of helium was obtained. The proof of the continuous production of the helium followed at once from the result of the next experiment. The emanation from the two quantities of the radium solution was allowed to accumulate until the equilibrium quantity was sufficiently nearly attained, which occurs practically in a period of two or three weeks. This was then pumped off with the hydrogen and oxygen simultaneously produced from the decomposition of the water, and freed from the latter by condensation with liquid air, and pumping off the volatile gases. As the tube warmed up a momentary glimpse of a spectrum characterised by bright green lines was always observed. This is probably the spectrum of the emanation, but it is masked immediately afterwards by the volatilisation of the carbon dioxide, which in our early experiments was never completely excluded. In experiments now in progress we have been able to overcome the difficulty, and the spectrum of the emanation is the subject of closer examination. If the spectrum of the sealed tube in which the emanation has been condensed is examined from day to day, the helium spectrum gradually makes its appearance and grows in brilliancy. The characteristic D_3 line appears generally after the third day, and in the end the complete spectrum is observed. This result has now been obtained many times, and proves that helium is formed from the emanation as one of the products of its disintegration. As the emanation changes into helium in the spectrum tube, a fresh crop of emanation is produced from the radium, and the process goes on indefinitely. The radium is being transformed into helium, *via* the emanation.

It must be understood that this result was only obtained by the utmost refinement of the experimental methods employed. In the long and arduous researches of Sir William Ramsay, and his colleagues Drs. Collie and Travers, into the rare elements of the atmosphere, the methods of dealing with infinitesimal quantities of gases with ease and certainty have been developed into an exact science. In addition, the extreme delicacy and distinctive character of the spectroscopic reaction of helium contributed to make the result possible. The smallest visible bubble at the top of a fine thermometer capillary, say one-hundred-thousandth of a cubic centimetre, or one-five-hundred-millionth of a gram, could be with certainty detected by the methods employed. The quantity actually obtained from the radium was certainly not many times greater than this. Even the production of this minute quantity of helium proves that the life of the radium cannot be indefinitely great, and this result had previously been arrived at by Professor Rutherford from the consideration of the probable number of α particles expelled per gram of radium per second, and the total number of atoms in a gram of radium. This point will be again referred to, but for the present some further and more recent results obtained by Sir William Ramsay and myself may be mentioned.

We have attempted by methods similar to those employed in dealing with minute amounts of helium, to obtain a measure of the absolute volume occupied by a given quantity of the radium emanation. This may be expected to be even less than the quantity of helium produced for two reasons. First, the emanation is much denser, and from measurements of the coefficient of diffusion undertaken by Professor Rutherford and Miss Brooks it is probable that the density lies in the neighbourhood of 80 ($H=1$). Secondly, the quantity does not continuously accumulate, but in the course of a few weeks attains an equilibrium value as already described. The equilibrium quantity is best expressed in terms of the time required to produce it. It can be shown that the equilibrium quantity of any transition-form of matter is that quantity produced in the period of the average life of the metabolon. Thus the quantity of emanation stored up by a radium compound when the maximum value is reached is that quantity which would be *produced* in 5·3 days of steady production. (The actual quantity *present* after this interval is of course smaller on account of the change it continually undergoes). The data obtained by Sir William Ramsay and myself show that the equilibrium quantity of the emanation from 60 milligrams of radium bromide occupies a volume between ·03 and ·04 cubic millimetre at normal temperature and pressure. The actual weight of radium in the compound employed is not accurately known, but it may be assumed without probably incurring serious error to be about one half of the total weight of the compound. The maximum amount of emanation stored up by one gram of radium (element) therefore occupies a volume of about a cubic millimetre.

One gram of hydrogen occupies the volume of 11·2 litres, and if its molecule were monatomic would occupy 22·4 litres. One gram of radium if it could be obtained in the form of a monatomic gas would therefore occupy a volume of $22{\cdot}4 \div 225 = 0{\cdot}1$ litre. It seems likely that the molecule of the emanation is, like argon, monatomic, since it shows no powers of chemical combination. With a density of 80, the atomic weight of the emanation would therefore be 160, and there is not room for more than one atom to be produced, from each atom of radium. In a cubic millimetre of emanation there are one one-hundred-thousandth of the number of atoms present in a gram of radium. If one atom of radium produces one atom of emanation, it follows that one one-hundred-thousandth part of the radium disintegrates in 5·3 days. The value of λ is therefore about 2×10^{-11}, and the average life of the atom is 1,500 years. Although this value is not likely to be very exact, and must be regarded as a preliminary estimate, it is probable that at least it approximates to the truth. If it is accepted a further important step may be made.

It is possible to deduce the average life of the radium atom from the disintegration theory alone without the datum just considered, at least in so far as to indicate a maximum and minimum value between which it must lie. The uncertainty arises from the fact that we do not as yet know the number of α particles expelled from each atom at each disintegration it undergoes. Obviously it cannot be less than one, and this fixes the minimum estimate of the life. On the other hand, if the radium atom is completely resolved into α particles not more than about 150 in all could be produced, which gives the maximum estimate. The method employed is as follows (compare for example Rutherford, *Nature*, Aug. 20th, 1903). The energy of the individual particle is about 5×10^{-6} erg. It can be argued that the radiant particle will possess by far the greater part of the energy of atomic disintegration, in the same way as when a gun is fired the major part of the energy is communicated to the bullet, and but a small part is used in the recoil. This holds good whatever the number of particles projected at each disintegration. If the energy emitted by a gram of radium per second (Curie and Laborde) is divided by the energy of the individual particle, the result, $2·4 \times 10^{11}$, is the number of α particles expelled by a gram of radium per second. If but one particle is projected at each stage, then since there are four stages in the disintegration of radium, at each of which α particles are expelled, one-fourth of the above number, or 6×10^{10} gives the number of atoms in a gram of radium that disintegrate per second. This is the maximum estimate, and the minimum is about 40 times smaller. Professor J. J. Thomson* has deduced from his own results and those of Townsend that there are $8{\cdot}7 \times 10^{23}$ atoms in a gram of hydrogen. The number in a gram of radium is therefore $3{\cdot}4 \times 10^{21}$. On the maximum estimate, the proportionate fraction of the radium changing per second is therefore $1{\cdot}7 \times 10^{-11}$, and the average life is about two thousand years. This is almost exactly the experimental estimate obtained directly from the volume of the emanation, and the result indicates that probably only one α particle is expelled at each disintegration.

The emanation of radium is a very interesting type of matter, for one half of it undergoes change in four days. Hence the behaviour of the tiny bubble of gas was investigated from day to day. In one experiment the volume steadily diminished with time roughly at the same rate and according to the same law as the activity decays. In about three weeks the volume had shrunk practically to zero, being less than one per cent. of that initially occupied. The question will be asked "What becomes of the helium produced?" This point is under examination. Rutherford has suggested that the α particle is actually an atom of helium, and since it is expelled with the velocity of 20,000 miles a second it is to be expected that it will penetrate the surface of the glass and remain imprisoned therein. We have actually found that glass which is subjected to this bombardment, when broken up and heated, gives off a quantity of helium, recognisable by its spectrum. A similar experiment, which however gave a negative result, is described by Curie and Dewar in the *Chemical News* for Feb. 19th, 1904 (p. 85). The decrease

* *Phil. Mag.*, 1903, s.6, v.5, p. 355.

of volume of the emanation with time is by no means uniformly observed, and it would appear that different kinds of glass act differently. In some it would appear that the helium after penetrating the glass slowly 'soaks' out of it without the assistance of heat. These points are under examination, and the results described must be understood to be of a more or less preliminary character.

As soon as it was realised that the radio-activity of a powerful element like radium is due to an insignificant fraction of the total number of atoms breaking up in the unit of time, it was evident that the internal energy bound up in the structure of an atom and released when it disintegrates is enormously greater than is ever associated with molecular structure. This view may be said to be experimentally proved by some recent work of Professors Rutherford and Barnes[1] on the heat emitted by the radium emanation. They found that if the emanation is released from a solid radium compound by heat, and condensed in a glass tube by means of liquid air, the heat-emission from the radium is much reduced, while the greater part is now emitted from the emanation. This result follows directly from the disintegration theory. Since only about one-fourth of the α particles expelled are derived from the initial disintegration of the radium, and three-fourths from the subsequent disintegrations of the emanation, it follows that when the emanation, etc., are removed the heating effect of the radium should be reduced to one-fourth the initial value, while the emanation, etc., should give three-fourths of the initial value. Hence the equilibrium amount of the emanation in one gram of radium emits 75 gram-calories of heat per hour. The total quantity of heat emitted during its complete life is given by multiplying the emission per hour by the average life of the

[1] *Phil. Mag.*, 1904, s.6, v.7, p. 202.

emanation in hours, and is therefore about 10,000 calories. The volume as we have seen is a cubic millimetre. The energy emitted by a cubic centimetre of emanation during its complete change is therefore 10^7 calories. This is a purely experimental result, and is independent of all hypothesis. The energy liberated on explosion by a cubic centimetre of hydrogen and oxygen in the proportion required to form water, is about two calories. The energy of the disintegration of the radium emanation is thus five million times greater than the energy of explosion of an equal volume of hydrogen and oxygen. This furnishes perhaps the most convincing proof of the argument that the energy of radio-activity cannot possibly be derived from the outside, or indeed from any other source than from the internal energy of the atom.

The above concludes the list of experimental advances that have been made since the inception of the theory of atomic disintegration. A few outstanding consequences and predictions remain to be experimentally verified, and some of these merit a brief consideration. It will be convenient to review the two main lines along which our knowledge of atomic disintegration has advanced. The transition-forms are recognised by their rapid rate of change, or more strictly by the large energy effects, relative to the actual quantity involved, which accompany the change. The ultimate products may be studied because they continuously accumulate, and if sufficient time is allowed or sufficient material is employed, will attain to quantities great enough to allow of direct recognition. The question arises as to whether a simple rigid line of demarcation between the two classes is allowable. In the table (p. 17) the known metabolons were arranged in the order of their average lives. The average lives in the case of uranium and thorium are assumed to be of the order of a million times greater than for radium, since the radio-activity is about a million times smaller. It will be seen that a fairly complete range of types is known, the average lives varying from a few seconds to a thousand million years. As the average life of a metabolon is increased it will partake more of the nature of a stable element and less of the nature of a transition-form. Consider the case of a mineral like pitchblende, in which there is a parent element A, disintegrating at an excessively slow rate through successive transition-forms B, C, D, E, etc., and let the respective rates of change be designated by λ_A, λ_B, λ_C, etc. A little consideration will show that after radio-active equilibrium is attained, since the amount of each type changing equals the amount produced, the actual amount of each type disintegrating will not depend on its own rate of change, but will be a similar quantity for all the types. The amount of each changing depends only on λ_A, and is independent of λ_B, λ_C, etc. This is a compensating principle of great importance. As the rate of change of a metabolon decreases, and its detection *in any given quantity* becomes increasingly difficult, the equilibrium quantity that accumulates correspondingly increases. The radio-activity of each type is expressed by $\lambda_A N_A$, $\lambda_B N_B$, $\lambda_C N_C$, etc., where N_A, N_B, etc., represent the actual number of atoms of each of these types present, and it is assumed that an atom of A produces one atom of B, etc. Since in radio-active equilibrium $\lambda_A N_A = \lambda_B N_B = \lambda\ N_C$, ... it follows that the amount of a transition-form accumulating is inversely proportional to its rate of change, or directly proportional to its average life. Suppose now that B, C, D are rapidly changing types, and that E is a very slowly changing type. It follows that when the mineral is separated into its various constituents by chemical analysis, *E* will not appear as a transition-form like *B*, *C*, *D*, but as a new radio-element, whose activity is sensibly permanent. Whether *E* is detected by its ordinary chemical reactions depends simply on its quantity, and this we have seen is proportional to its average life. If a sufficient number of tons of the mineral are worked up, it will appear as a new powerfully radio-active element.

Viewed in this light it seems probable that the new elements radium, actinium, and polonium are merely slow changing transition-forms produced in the disintegration of the parent-element uranium. The quantity of radium in pitchblende is about one-millionth part of that of the uranium, and its average life as judged by the activity of unit weight is about a million times less. For polonium, if we assume, as seems probable, that Marckwald's work on radio-tellurium applies really to Mme. Curie's element, the quantity present is less than four milligrams to two tons of material. The average life of polonium we know from the observations of Mme. Curie is slightly greater than a year, or about one thousandth of that of radium. These considerations are of course not strictly quantitative in their application, but apply to the order of the quantities that may be expected.

The case of polonium may be first considered. Since the activity of this type decays to half-value in about a year, it follows without doubt that the existence of polonium in pitchblende at the present time must be due to its continuous production in the mineral. The only question is as to the nature of the parent-element and the stage of the disintegration at which polonium is produced. There is a phenomenon recorded by Mme. Curie in her thesis which perhaps has a bearing on this question. When the "induced" radio-activity of radium decays, it diminishes regularly in a geometrical progression with the time, falling to half value every 30 minutes. But when it has fallen to about one twenty-thousandth of its initial value it no longer decays but remains sensibly constant over long periods of time. This phenomenon Mme. Curie terms 'the induced activity of radium with slow rate of dissipation.' The question suggests itself 'Is polonium the cause of the phenomenon?' The disintegration series of radium would then read :—

Radium.
↓
Radium Emanation.
↓
Matter causing induced activity I.
↓
ditto II.
↓
ditto III.
↓
Polonium.
↓
?

One fact seems to favour the suggestion. If λ_1 is the radio-active constant of polonium, and λ_2 that of the type of matter which produces it, on the principles already discussed, the ratio of the activity of the polonium, after the change is complete, to the initial activity of the matter producing it, should be a number of the order of $\frac{\lambda_1}{\lambda_2}$. Since this ratio as given by Mme. Curie is $\frac{1}{20{,}000}$, we can deduce $\lambda_2 = 6 \times 10^{-4}$. λ for the last stage of the matter causing the induced activity is $3{\cdot}8 \times 10^{-4}$.

The point seemed worthy of an experimental investigation, and I have been examining the phenomenon of induced activity with slow dissipation. Polonium, it has been mentioned, is characterised by the peculiarity that it gives only α rays. The activity under consideration was found to consist of both α and β rays, but the proportion of the β rays is very small, being only one-tenth of that for the case of a thin layer of uranium oxide. The matter causing the activity is not, however, homogeneous. A portion is very easily volatilised when the glass on which it is deposited is heated in a test-tube over a bunsen flame, and this part is deposited on the quite cold walls of the tube. It will be remembered that polonium is easily volatilised. Perhaps more definite information will be given when the specimens are re-examined after an interval, and possible intermediate changes have completed themselves. The point of course is that unless polonium can be accounted for in this way there must exist another more or less permanent radio-element in pitchblende, for the matter causing the induced activity with slow dissipation must go on accumulating in pitchblende until its activity is comparable with that of the other disintegration products.

The view that polonium is a disintegration product of radium is at first sight strongly confirmed by some experiments of Giesel.* Giesel, repeating the method applied by Marckwald for the separation of polonium from pitchblende, kept pieces of bismuth, palladium, and platinum respectively in solutions of powerful radium preparations. He obtained a sensibly permanent activity consisting only of α rays from the metals after they had been freed from every trace of radium and left to themselves for a few days. He remarks that this is in support of his earlier expressed view that "Polonium durch Radium inducirtes Wismuth sein könne." It would seem that polonium might equally well be described as induced platinum, or induced palladium. On the disintegration

* (Ber. d. Deutsch. Chem. Ges., 1903, p. 2368.)

theory Giesel's result may be translated to mean that polonium is *produced* from radium and *deposited* from the solution on bismuth, platinum, and palladium. He further found that the radioactive deposit was formed on a wire held in the air above the solution, which is in accordance with the above conclusion that polonium is produced from the matter causing the induced activity, which itself is produced from the emanation which would diffuse into the air above a radium solution. But as the residual activity so produced certainly in my experiments gave β rays, although in feeble intensity, some doubt is thrown on the whole result and whether the activity on the metals left in the solution was also completely free from β radiation. This explanation, therefore, cannot be regarded as quite proved at the present time.

If the time of our observations could be extended from a few years to a few thousand years, the arguments advanced for polonium would apply with equal force to the case of radium. This element, from its known rate of change, must also be a transition-form, and its present existence can only be accounted for on the view that it is being reproduced in the minerals as fast as it disintegrates. I have been conducting some experiments during the past year to try to determine experimentally whether a quantity of uranium, originally free from radium, would not grow a crop of the latter element in the course of time. But the experiments have hardly been carried on long enough at present to furnish conclusive results. Many objections, it is true, can be urged against the view, but it remains to be seen whether they are real or apparent. There is one very great unknown factor in these considerations, and that is actinium. Until this element becomes available for exact study, the possibilities that have to be taken into account in attempting to delineate the complete course of the disintegration process causing the radio-activity of pitchblende, are too numerous for any definite prediction to be made. Certain considerations seem to point to actinium being an intermediate transition-form between uranium and radium.

These considerations have been introduced to show that it is at least possible, although not yet definitely proved, that all radio-active matter may be transition-forms in the disintegration of the heaviest known elements, uranium and thorium, and that these two may be considered as the prototypes of the fifteen other types now known. The advantage of this is obvious. We have seen that the average lives of these two elements is of the order of at least 10^9 years. This is a period so great that it carries us back to the probable limit of the existence of the earth as a separate planet. We have no difficulty in supposing that the disintegration of these elements has been proceeding continuously at a rate similar to that at present, during the past epochs demanded by other considerations as the necessary age of the earth. It is not absolutely necessary, therefore, to assume that there has been any concomitant process of reproduction. The geological estimate of the necessary age of the earth, which is the maximum that has yet been demanded, is only a hundred million years, or one-tenth of the average life of the uranium and thorium atoms. Hence the cosmical processes of separation which occurred in the early history of the earth, and resulted in its present non-homogeneous composition and the grouping of the elements into the various minerals known to us to-day, may well have occurred within the lives of the uranium and thorium which exist in the earth's crust at the present day. The theory of atomic disintegration, without complementary upbuilding, does not conflict with the ideas formed as to the duration of the universe from the study of other processes of evolution. Of course, it is not denied that a complementary process of upbuilding may occur. All that the argument is intended to convey is that such a process is not necessitated by the present state of knowledge.

For, if we would push the enquiry further and demand to know how and when the heaviest forms of matter originated, we are face to face with the fundamental problem on which no science has yet thrown light. How and when did the universe originate? All processes of evolution that have been so far revealed have been all in the one direction, and demand therefore a beginning and an end. It is not difficult to see what the end must be if the progress in the present direction is maintained. There is no escape, according to current orthodox conceptions, from the conclusion that the universe is tending to a state of exhaustion in which all change must cease. With regard to its origin it is sufficient if it is considered to refer to one only of the three fundamental dimensions, mass, space and time, for each is meaningless without the other two. The simplest idea that it is possible to hold of the nature of the initial creative act is to suppose that it refers to time. The universe may be likened to a wound-up clock, the creative act being the starting of the clock. How long the clock has existed before it was started, and how long it remains in existence after it has run down, are questions without meaning, for the conception of time without change is impossible, and mass and space also only exist with reference to time.

The other alternative is to consider evolution as proceeding in cycles continuously, or in other words to suppose that for every process going on in the one direction there occurs a complementary process in the opposite direction. This, if practicable, certainly offers a more consistent solution of the problem. The difficulty in the past to this view seems to have been the Second Law of Thermodynamics, that when a change of energy occurs spontaneously in the one direction, it cannot of itself proceed in the opposite direction. But it would seem that in this law, as stated, there is the same confusion between personal inability and natural impossibility, which has been pointed out elsewhere. Because the chemist's atom never suffered subdivision in *known* processes, it was in danger of being regarded as indivisible with reference to all the agencies of nature, known and unknown. Is not the whole question of the possibility of a perpetual cycle of energy-change in the processes of cosmical evolution in a somewhat similar position to that occupied by the atomic theory before the discovery of radio-activity? Clerk Maxwell has shown by his 'sorting-demon' that it is very easy to imagine a process by which heat of itself would pass from a lower to a higher temperature, and history indicates that the resources of Nature are generally much beyond the utmost capacity of the human imagination. On future discoveries in this connection depends whether science is or is not forced to accept a limited philosophy with regard to the universe, in which the idea of a creative agency is the necessary starting point, and universal death the ultimate goal.

The difficulties in avoiding this view are certainly very great. We know from the energy emitted by a disintegrating atom, the absorption that must take place if that atom is to be reconstructed out of its constituents, and this is so great that, even if heat of uniform temperature is considered available, it is difficult to imagine how it can be furnished from its surroundings unless a considerable area is taxed for the supply. At first sight it seems that the atomic theory, which bears out and is borne out so strikingly by atomic disintegration, opposes a barrier to any conception of atomic up-building. A gradual and continuous accretion of atomic mass in which the energy was supplied in very small steps as available from the low-grade heat energy of the surroundings seems the only process readily conceivable. But the atomic theory appears to demand equally with a *per saltum* degradation, a *per saltum* accretion. This difficulty is however not real. We have only to account for the step-by-step increase in the complexity of atoms *as known to us.* It is not necessary to assume that it is impossible for intermediate forms (representing a practically continuous increase of atomic mass from the lightest to the heaviest known atom) to be altogether incapable of existence. All that is required is that the rate of accretion of mass should be more rapid between the points of stability as represented by the atoms of the periodic table. This would ensure that the intermediate-forms in the up-building process, like the transition-forms in that of disintegration, would never accumulate in sufficient quantity to have been yet detected by direct methods. These views belong at present to the realm of pure conjecture, but it is an era of speculation with regard to the constitution of matter, and the more the problem is regarded from independent points of view the more likely is the speculation to prove fruitful. The old order changeth, giving place to new. Electrons are regarded as constituents of atoms, and from that view to the ideas advocated by Sir William Crookes that atoms are composed entirely of the same constituent or protyle is at least a possible step. Is an electronic accretion of atomic mass as indicated above within the regions of possibility?

As science has advanced, the limitations of the universe with reference to the extent of its past and future existence have been forced steadily back. By the discovery of radio-activity and the revelation that has followed, of the vast and hitherto unsuspected stores of energy associated with the atomic structure of the more complex forms of matter, the possibilities of its life in both directions have been enormously extended. The extension in the present state of knowledge cannot, however, be regarded as anything more than of the nature of a reprieve. The end has been postponed, not avoided. In spite of these advances cosmical history still opens with a mysterious origin and closes with the pronouncement of an inevitable doom. None will believe that the last word has yet been spoken. There is at least a dawning probability that by further discoveries the two insoluble enigmas of philosophy may be avoided, and that ultimately the universe may be regarded as a truly conservative system, limited with respect neither to the future nor the past, but proceeding through continuous cycles of evolution.

Manchester Memoirs, Vol. xlviii. (1904), *No.* 9.

IX. An Interesting Reaction of Copper Salts.

By EDMUND KNECHT, Ph.D., F.I.C.

Read December 15th, 1903. Received February 15th, 1904.

As is well known, the salts derived from titanium sesqui-oxide, Ti_2O_3, are powerful reducing agents. More than fifty years ago, Ebelmen, who was the first to describe the chloride, drew attention to the fact that the aqueous solution of this salt was capable of reducing gold, silver and mercury from their salts, while, according to the same authority, cupric salts are thereby reduced to the cuprous and ferric salts to the ferrous condition; on this latter reaction I have based a method of estimating iron in the ferric condition which is both rapid and accurate.

By the addition of titanous chloride to the solution of a cupric salt, I find that in the first instance a reduction takes place in the sense alluded to by Ebelmen, *i.e.*, cuprous chloride is precipitated, but on adding excess of the titanium solution, the white precipitate is redissolved and after standing for some time, or better still by warming, metallic copper is precipitated. The reaction, which only takes place in presence of considerable excess of the titanous chloride, is however incomplete; it is in fact a reversible one, and a method of producing the titanous salt is based upon the action of metallic copper on the tetrachloride.

But if titanous sulphate is employed in place of the chloride and the copper solution is not too dilute, instant precipitation of metallic copper takes place, even when the reagent is not added in sufficient amount to form a cuprous salt. By adding excess of the reagent, the whole of the copper comes out as such, presumably according to the scheme :—

$$Ti_2O_3 + CuO = 2TiO_2 + Cu$$

but up to the present I have not been able to verify its correctness quantitatively. Failure in this respect has been partly due to the fact that the precipitated copper is so finely divided that it is found impossible to filter it, while on the other hand its intense colour prevents the use of an indicator in titrating back the excess of titanous sulphate. Moreover, even if it were possible to filter the precipitate, another drawback presents itself, inasmuch as the metal is in such a fine state of division that in contact with the air it is rapidly oxydised and is liable to be partly redissolved by the excess of sulphuric acid which must of necessity be present. In using the reaction as a test for small quantities of copper, this phenomenon accounts for the disappearance of the precipitate after the liquid has been left exposed to the air for some length of time.

With very dilute solutions of copper (one part or less of the metal in 10,000) the reaction with titanous sulphate is not instantaneous, requiring from 2 to 30 minutes for its completion. Under these conditions, it does not in fact show at all at first, but by degrees the solution acquires a dull pink colour, different from that of the titanous sulphate, and only after this the metal makes its appearance. The reaction is best observed by reflected light ; transmitted light is of no use, showing only a bluish-green colour when appreciable quantities of the metal are present, and nothing at all in presence of minute quantities. The reaction can be accelerated by the application of heat, but the precipitated metal is never so bright as when operating on cold solutions. In any case boiling should not be resorted to since this will bring down titanic hydrate which will spoil the delicacy of the reaction. The presence of small quantities of hydrochloric and nitric acids does not mar the reaction, neither is it affected by the presence of the sulphates of metals other than those of the noble metals and of bismuth. Its use as a reagent in group II. is thus precluded.

Apart from the fact that the reaction which I have referred to is the only one (as far as I have been able to ascertain)* in which metallic copper is precipitated from the aqueous solution of one of its salts by a soluble reducing agent, I think I may claim that owing to its great delicacy it will be found of some practical use, especially as a "demonstratio ad oculos" of the presence of copper.

The limit at which the reaction is visible is, as far as dilution is concerned, one part of copper in one million of water, using a cylinder of 3in. diameter. As regards the limit in actual weight of metal, this will, of course, depend upon the smallest volume of liquid that it may be convenient to employ, but taking 5 cc. as a basis, the weight of copper which is still clearly discernible is 0·00001 gramme (equal to 0·001 per cent. on the gramme standard). In using the reaction for the detection of copper in dyed textile fabrics, from one to five grammes of the material are incinerated in a small porcelain dish, the ash taken up by dilute nitric acid, and evaporated down on the waterbath with the addition of a few drops of dilute sulphuric acid. The residue is then taken up in a minimum of water and

*Since writing this paper, I find that J. Meyer, in describing some of the properties of hydrosulphurous acid (*Zeitschrift für anorg. Chem.*, 1903, p. 43) mentions that this substance will precipitate metallic copper from dilute acid solutions of its salts. I have repeated this experiment with the commercial "Hydrosulphite N F" of Meister, Lucius & Brüning (a double compound of hydrosulphite and formaldehyde) and find that a precipitate is obtained which resembles that produced by titanous sulphate, but the reaction is not nearly so delicate.

tested as described. Other substances such as tinned vegetables may be similarly examined.

The reaction does not lend itself to the estimation of traces of copper by colorimetry, since comparison by transmitted light is useless for small quantities. Even if a means of comparing the precipitates by reflected light (which would involve devising and fitting up of special apparatus) could be devised, it is doubtful whether such a method would take the place of the recognised and more convenient ferrocyanide test.

In conclusion, I may be permitted to draw attention to the remarkable behaviour of an acid solution of titanous chloride towards mercuric chloride. In consequence of the powerful reducing action of the former, one would expect instant precipitation of metallic mercury, but although such precipitation does take place on boiling, no change is noticed in cold solutions beyond the formation of a very slight quantity of a crystalline precipitate, the composition of which I have not ascertained. Metallic mercury vigorously shaken with a solution of titanic chloride, yields a small amount of the titanous salt and the reaction is therefore a reversible one, as in the case of copper, but this fact nevertheless does not explain the non-precipitation of mercuric chloride in the cold.

Manchester Memoirs, Vol. xlviii. (1904), *No.* **10**

X. On the Spectrum of the Glow Discharge at Atmospheric Pressure.

By G. A. HEMSALECH.

Communicated by Dr. C. H. Lees.

Read February 16th. Received February 23rd, 1904.

1.—*Production of the Glow Discharge.*

When the ordinary induction coil discharge is taken in air, the electrodes being about one centimetre apart for a 10-inch spark coil, a violet glow is seen near the end of the negative electrode. When the electrodes are brought very near together, the glow is seen at both electrodes simultaneously.[1] In this case the discharge of the coil is oscillatory, the oscillations being very slow.

The special interest which is attached to this glow is the discovery recently made by Sir William and Lady Huggins[2] that radium, in an atmosphere of air at ordinary pressure and temperature, spontaneously emits a spectrum which coincides with or is very similar to that of the negative glow as obtained in the ordinary coil discharge.

This exceedingly interesting result induced me to try a few experiments on the glow discharge at atmospheric pressure, which, so far as I know, has received little attention from spectroscopists.

The glow discharge is obtained in a very striking manner when the oscillations of a powerful condenser discharge are slowed down by inserting a self-induction

[1] Lecoq de Boisbaudran, "Spectres Lumineux," p. 30.

[2] Sir William and Lady Huggins, *Astroph. Journ.*, vol. 18., pp. 151 & 390, 1903.

of about 0·04 henry in the discharge circuit. Copper and silver electrodes are particularly effective in producing the glow, especially when they are placed very near together; the glow is then seen to extend to some distance up the sides of the electrodes.

But under ordinary conditions the glow is a very unstable phenomenon; sometimes it appears at one electrode, sometimes at the other; at other times again it will appear at both simultaneously, and then again not at all; hence it was quite impossible to produce the glow at will.

Now, it was found that the glow was always accompanied by an enormous heating of the electrode and it was thought possible that the heating might really be the cause of this glow.

An experiment made on these lines proved at once successful: by simply heating the electrodes the glow could be obtained on either of them at will. Also other metals with which the glow had not been observed before could be made to produce it. The heating may be effected either by means of a Bunsen burner or electrically.

The glow produced in this way is very brilliant and sometimes extends to a distance of from 5 to 8 mm. up the electrode, the latter being 2 or 3 mm. in diameter. The glow is seen to be entirely confined to the surface of the metal.

Analysed by means of an oscillating mirror the glow is seen to appear alternately first at one and then at the other electrode in accordance with the alternations of the oscillations in the discharge. Also the sharp images of the glow as seen in the mirror reveal the fact that the phenomenon must be almost momentary.

The spectrum of the ordinary coil discharge in air between electrodes about 1 cm apart is reproduced in

Fig. 1 of *Plate* VI. The image of the spark, which was placed parallel to the slit, was projected on to the latter, and thus permitted one to follow the changes in the spectrum along the spark gap, according to Lockyer's method. The bands, which are seen to go right across from the anode (top) to the cathode (bottom), form the positive band-spectrum of nitrogen. From the anode are also seen to emerge certain lines of the line spectrum of nitrogen; these do not go right across, but only traces of them can be seen in the glow of the cathode. The most brilliant spectrum is seen in the cathode glow (bottom), where, in addition to the positive bands, two new bands appear, whose heads are at $\lambda = 3914{\cdot}4$ and $\lambda = 4277{\cdot}8$. These are the characteristic bands of the negative band-spectrum of nitrogen, and of the glow discharge in air.

2.—*Spectrum of the Glow Discharge in Air.*

The glow was obtained by heating the electrode, and an image of the glow was projected on to the slit of a glass prism spectrograph. A remarkable feature of this spectrum (*Fig.* 2, glow on Cu electrode) seems to be the great energy concentrated in the heads of the principal negative bands. This is perhaps an indication that the stimulation of the nitrogen ions is effected impulsively and momentarily. Some of the brighter air lines of the line spectrum are also seen in the glow, their appearance is very hazy; also the principal metal lines are faintly visible.

In the following table are contained the chief bands of the spectrum of the glow discharge in air, the wave lengths referring to the heads of the bands. For the sake of comparison I have added a list of the radium glow bands (deduced from the photograph published by Sir W. and Lady Huggins, *l.c.*) and of the negative and positive bands as observed in vacuo. My observations which were made with a glass prism, extend only to $\lambda = 3570$ about, but no doubt the last three bands of radium observed by Sir W. and Lady Huggins will also have their corresponding bands in the glow discharge.

Glow Discharge at Atmospheric Pressure.	Radium Glow.	Vacuum Tube.	
		Negative Pole.	Positive Pole.
4277·8	4280	4278·6 Hasselb.[1]	.
4058·5	4065	...	4059·0 Hasselb.[1]
3997·2	4000	...	3998·0 ,,
3914 4	3914	3914·4 Deslandres[2]	...
3804·4	3800	...	3804·8 Deslandres[2]
3755·2	3760	...	3755·1 ,,
3576·6	3580	3582·3 ,,	3576·8 ,,
...	3545	3549·0 ,,	3537·2 ,,
...	3370	...	3372·5 ,,
(3155·7 Berndt,[3] oscill. spark)	3155	...	3158·7 ,,

This band spectrum of the glow discharge is very characteristic in that it consists of bands selected from both the negative and positive band spectra of nitrogen. It seemed interesting to see whether these two band-spectra had a separate and distinct existence at atmospheric pressure. The negative band spectrum is easily obtained by the introduction of some self-induction in the discharge

[1] B. Hasselberg, *Mém. Acad. Saint-Pétersbourg*, t. 32, No. 15, 1885.

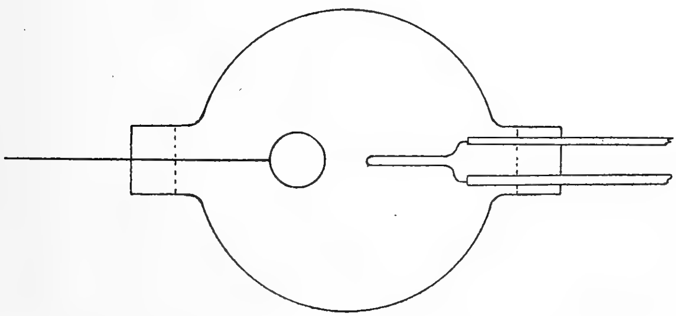
[2] H. Deslandres, *Thèses de doctorat*, Paris, 1888.

[3] G. Berndt, *Drude's Ann.*, Vol. 4, p. 788, 1901.

circuit of a condenser.[1] On increasing the self-induction considerably, it was found that the negative bands gradually disappeared, and were replaced by the positive bands. The gradual change from the negative to the positive band spectrum is shown in *Fig.* 5. Here the self-induction varied from 0·04 henry (top), to 0·7 henry (bottom). In the top spectrum the negative bands at 3914 and 4278 are well developed, and there are hardly any traces of positive bands. In the bottom spectrum the positive bands are fully developed, and the negative bands have disappeared.

3.—*Glow Discharge in Hydrogen.*

The electrodes were enclosed in a glass bulb through which a steady current of dry hydrogen was passing continuously. One of the electrodes was formed by a bent copper or platinum wire through which a current from a battery could be sent to heat it. (See *Figure*)



The other electrode consisted of a brass sphere or copper rod ; the distance between the electrodes was about 1 cm. When the oscillatory spark discharge was started no glow was at first visible. But as soon as a current was sent

[1] Hemsalech, *Thèses de la Faculté des Sciences*, p. 111, Paris, 1901.

through the wire electrode and the latter thus became heated, the glow gradually developed and finally extended for one centimetre or more along the electrode, running up both branches of the wire. The glow seems to be confined to the surface and is of a brilliant grey colour. When the current through the wire was stopped the glow disappeared. It is not necessary that the wire should be heated to a red heat in order to obtain the glow.

Sometimes the spark itself became surrounded by a deep blue glow forming a hollow envelope round the spark. The origin of this blue envelope and the conditions which determine its appearance are still unknown.

A glow was also obtained on the other electrode (not heated) at the point where the stream of electrons strike the brass sphere.

When the glow was produced on a copper wire, a green vapour was constantly seen over the opposite electrode. The spectrum of this vapour has not yet been examined ; it looks as if the copper wire disintegrated by the action of heat and the matter, instead of being deposited on the opposite electrode, is repelled from it and forms a luminous cloud above it.

A very interesting case of metallic deposition was observed with a heated platinum wire. When the glow discharge had been kept up for about half an hour or even less a very bright deposit of metallic platinum was obtained on the other electrode. On a polished surface this deposit acquires the same polish as the surface. The diameter of this deposit was about 3 to 5 mm., it is surrounded by platinum black. I do not know whether this metallic deposit at atmospheric pressure has been observed before ; possibly it may be an ordinary case of "Zerstäubung."

Spectrum of the Glow Discharge in Hydrogen.

The spectrum consists of lines of both the elementary and the compound line spectra of hydrogen; the lines are very sharp, just as they are obtained in Geissler tubes. they are sharper even than the lines of the oscillatory spark[1] itself for an equal value of self-induction. Besides these hydrogen lines, there are also visible lines of the metal constituting the wire; and with a platinum wire the edges of the two negative bands of nitrogen, $\lambda=4278$ and $\lambda=3914$, stand out very prominently. When a copper wire was used, these bands were barely seen and it seems probable that their presence is due to the well-known fact that platinum absorbs nitrogen and gives it off on heating. A photograph of the hydrogen glow spectrum is reproduced in *Fig.* 3 of *Plate* VI.

4.—*Glow Discharge in Oxygen.*

To produce the glow the platinum wire needs to be heated very little and only at the beginning, the wire soon afterwards becoming red hot and remaining so throughout the duration of the sparking. The presence of the glow can only be revealed by the spectroscope on account of the red or even white heat of the wire. The spectrum is that of the elementary line spectrum of oxygen with the most intense line at $\lambda=4415{\cdot}3$A. Of other conspicuous lines are to be noted the edges of the negative bands of nitrogen at $\lambda=4278$ and $\lambda=3914$, their presence being due to the absorption of this gas by the platinum. The spectrum of the oxygen glow is reproduced in *Fig.* 4 of *Plate* VI.

Behaviour of the Calcium lines in the Glow Discharge.

These lines have attracted much attention of late years and it seemed useful to just record their behaviour under

[1] Hemsalech, *Comptes Rendus*, t. 129, p. 288, 1899.

the conditions presented by the glow discharge. In the nitrogen glow the H and K lines are very strong, K especially is very marked whereas the blue line at 4226 is feeble. In hydrogen, on the other hand, the blue line is very strong and the H and K lines rather faint. In oxygen the blue line is also very strong but of the H and K lines only K is just visible.

5.—*Conclusions.*

The effect of heating a wire is to ionise the gas in its neighbourhood, and the ionisation is at the surface of the heated metal, and does not extend to any considerable distance in the gas. When the charge on the cathode leaps across the air gap, the electrons will not only break through at the end nearest to the anode, but will force their way out at all places within a certain distance from the end, and, shooting through the thin layer of ionised gas, will stimulate its ions to send out vibrations, and thus give rise to the glow round the cathode.

The results obtained with the glow discharge and the ordinary coil discharge in air tempt us to draw some conclusions as to a possible origin of the three types of nitrogen spectra, viz., the *line* spectrum, the *negative*, and the *positive* band spectra.

From the researches of Schuster, J. J. Thomson, and others, we know that the spark discharge is initiated by the expulsion of positive ions from the anode, and of electrons from the cathode. The positive ions bombard the cathode, and help to disentagle the electrons from the surface of the cathode. The positive ions will be densest near the anode, and the negative ions will be very dense near the cathode. Now when the discharge takes place the electrons, by virtue of their greater velocity, will for the most part shoot through the layer of negative ions, and in this way cause the glow which gives the negative band spectrum. After having passed through the negative ions, they will encounter near the anode the positive ions, moving at a much slower rate; they will collide or combine with some of them, giving rise to a spectrum peculiar to the anode and its neighbourhood, namely, the line spectrum of nitrogen. The positive ions, after their encounter with the electrons, will now meet the negative ions, which also move at a slower rate than the electrons, and their collisions with each other, or with complete molecules of the gas, will set up vibrations all along the spark gap, which will constitute the positive band spectrum. The existence of some rays of the line spectrum in the glow may be explained by the positive ions, which bombard the cathode to free the electrons.

Thus, on the above view, the spectra of nitrogen may be accounted for in the following manner:

1. The *line spectrum* is the result of the, possibly interior, vibrations of the positive ions, brought about by collision or combination with electrons.
2. The *negative band spectrum* is the result of encounters between negative ions and electrons.
3. The *positive band spectrum* is the result of encounters between positive and negative ions, or between ions and molecules.

Deslandres has recently given an explanation of these spectra,[1] which differs slightly from the above. He does not distinguish between ions and atoms, and according to his view the vibrations are caused by encounters, combinations, or decompositions of electrons, atoms, and molecules.

[1] Deslandres, *Comptes Renaus*, t. 137, p. 1013, 1903.

Origin of the Radium Glow.

Comparing the luminous glow of radium with that of the glow discharge in air we find, according to the observations of Sir William and Lady Huggins, that the two phenomena are very similar.

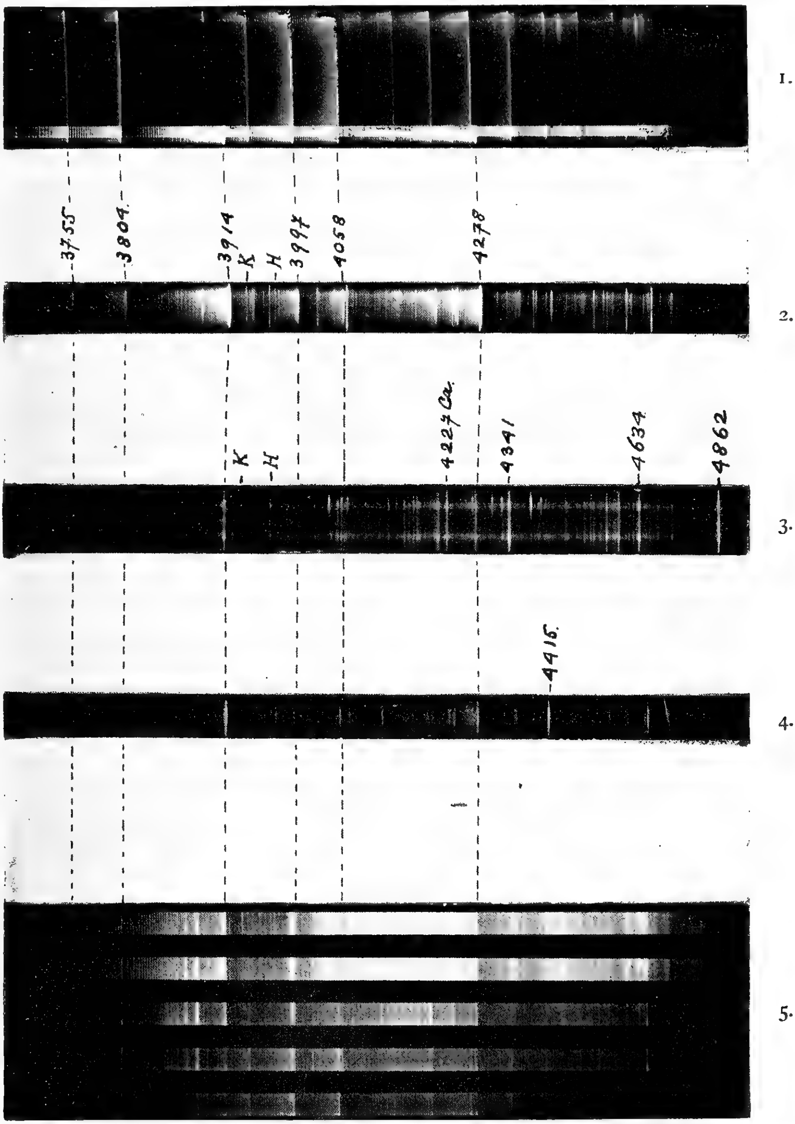
The glow of radium is confined to the surface only, and does not extend into the air. The spectrum of this glow is the same as that of the glow discharge in air. On heating radium, the luminosity of its glow is increased. We do not, however, know the cause of the spontaneous emission of electrons, nor exactly how the ionisation on its surface is effected. But very probably the emission of electrons, and their breaking through a thin layer of ionised air, is the direct cause of the glow.

Let us suppose that radium possesses the property of absorbing negative ions of nitrogen; then, as these diffuse into the radium, they will encounter at the boundary surface the stream of electrons moving outwards. The collisions which will ensue will give rise to the glow giving the negative band spectrum. Now supposing that these negative ions in diffusing into the radium are being deprived of not only one, but of several of their electrons, such that they pass through the neutral state into that of positive ions, then the number of free electrons and of positive ions in the radium would increase. Now as more and more negative ions are being absorbed, the electrons and positive ions will be driven out again, and thus give rise to two different kinds of radiations: one consisting of electrons and constituting the β rays, and another one consisting of positive nitrogen ions, and forming the α rays of radium. The α rays on their way out will encounter the in-going negative ions, and thus give rise to the positive bands of nitrogen in the radium glow. The highly penetrative γ rays could perhaps be explained by assuming an impulsive expulsion of electrons, giving very abrupt impulses to the ether. One result of such an impulsive expulsion of electrons would probably be a concentration of energy in the heads of the nitrogen bands in the radium glow. Whether such is the case I do not know.

Hence on the view expressed above, the action of radium would consist in absorbing negative ions of nitrogen, transforming them on their diffusion through it into positive ions and electrons, and giving off again the product impulsively. In fact, radium acts like a condenser, being charged up with negative nitrogen ions, and discharging impulsively electrons and positive ions.

It would be interesting to place radium in an atmosphere of hydrogen, and see if it would continue for some time to emit the nitrogen bands. If this were the case, then the assumption that nitrogen ions are absorbed by the radium would be true. That nitrogen and also helium are easily absorbed by platinum is well known. The same may be true for radium.

PHYSICAL LABORATORY OF THE UNIVERSITY,
MANCHESTER,
February, 1904.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Manchester Memoirs, Vol. xlviii. (1904), *No.* **11**.

XI. On a Suitable Arrangement for Determining the Capacity of a Condenser by the Method of Successive Discharges.

By H. MORRIS-AIREY, M.Sc. and E. D. SPENCER.

(Communicated by Dr. C. H. Lees.)

Received and Read February 16th, 1904.

The necessity for having some quick and reliable method for determining absolutely the capacity of a condenser is well known, especially where the condensers are used on alternating current circuits.

The usual method given in text-books involves considerable expenditure of time, and a sensitive ballistic galvanometer is required, if accurate results are to be obtained, and consequently Maxwell's method of successive discharges has been adopted in practice, with much success.*

The theory of the method may be briefly described as follows :—

We can regard capacity as the quotient

$$\frac{[\text{Quantity of Electricity}]}{[\text{Difference of Potential}]}.$$

This may also be written

$$\frac{[\text{Current} \times \text{Time}]}{[\text{Current} \times \text{Resistance}]}.$$

Hence it should be possible to determine a capacity from measurements of time and resistance alone.

Imagine a circuit containing a battery of electromotive force E, a galvanometer of resistance G, and a key $Q.P.S.$

*Thomson and Searle, *Phil. Trans.*, 1890, A, p. 583.

connected to a condenser in the manner shown in the diagram. If P is connected to Q, the plates of the con-

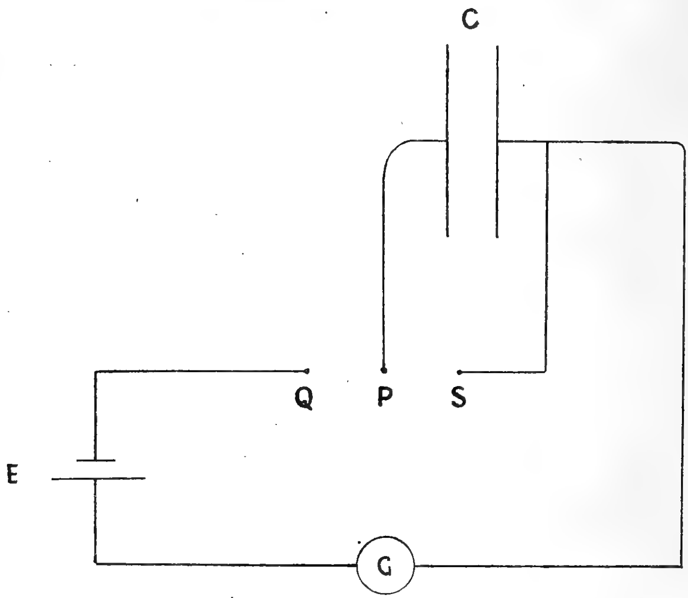


Fig. 1.

denser become charged, and a quantity of electricity equal to EC passes through the galvanometer. If P is joined to S, the condenser is discharged. On performing this operation n times per second, a quantity of electricity equal to nEC passes through the galvanometer. If the time of swing of the galvanometer needle is great compared with the time of vibration of P, the galvanometer shows a permanent deflection corresponding to the passage through it of a current of strength nEC.

Now replace the condenser and key by a resistance R, adjusted so that the galvanometer deflection is the same as that obtained with the condenser in circuit. The current flowing through the galvanometer $\left(\text{viz.,}\ \frac{E}{R+G}\right)$ must equal nEC. Hence $nC = \frac{1}{R+G}$.

Knowing the frequency of the vibrating key, and the resistance of the galvanometer, we thus obtain the value of the capacity in electro-magnetic units.

In Thomson and Searle's application of this method, a rotating commutator was employed to work the condenser key, and with n equal to 64, the direct deflection method described above was found to give unsteady deflections, and a zero method using a form of Wheatstone's Bridge was substituted.

Such a rotating commutator is, however, not always available in a general physical laboratory, and it was decided to use an electrically driven tuning fork to work the key.

Two small rigid riders of aluminium were fastened to

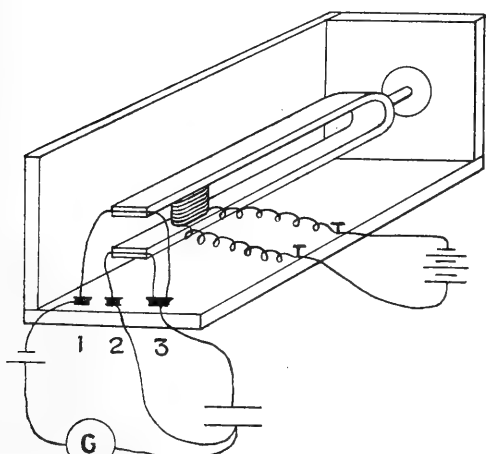


Fig. 2.

the prongs of the fork, both of which dipped into a common mercury cup (3) on one side, and into separate insulated mercury cups (1) and (2) on the other. The level of the mercury in these cups was adjusted by raising or lowering two pegs, which were partially immersed in the mercury, so that when the prongs of the fork were excited and approaching each other, the lower rider was lifted out of the cup (2), and the upper rider descended into the cup (1). Similarly, when the prongs were separating, contact was made in cup (2), and broken in cup (1). The terminals of the condenser were connected to the cups (3) and (2); the one connected to (2) being also connected through a galvanometer to one pole of a cell, the other pole of which was connected to the cup (1). According as contact was made in cup (1) or cup (2), the condenser was charged or short-circuited.

When the fork was set into vibration, a steady deflection of the galvanometer needle was obtained, which could be adjusted to a convenient amount by varying the galvanometer shunt. The condenser and key were now replaced by a standard resistance box, which was adjusted until the deflection obtained was the same as that obtained with the condenser. The value of n, which was in the first place determined by comparison with standard tuning forks, and found to be 123·4, was from time to time verified by means of the results obtained with a standard condenser.

As the capacity of the riders, which were insulated from the fork, was very small compared with the capacities to be determined, no correction for the key was necessary. Some trouble was experienced at first in establishing good contacts at the mercury cups, owing to the action of the mercury on the metal riders, the resulting galvanometer deflections being unsteady. After copper, brass, steel, and iron had been rejected, polished aluminium was finally adopted, as with pure mercury it was found possible to use these contacts for several weeks together; the contacts now occurred with the greatest regularity, and the position of the galvanometer spot could be read off to a tenth of a millimetre on a scale one metre distant from the galvanometer.

The values obtained for the standard condensers at our disposal were absolutely consistent, and some condensers used in the Electrical Engineering Department of the Owens College were examined. The effect of the high voltages to which they had been connected was very noticeable.

The following are a few typical results obtained:

Condenser.	Capacity.	Equivalent Resistance.	Galvanometer and Shunt.	Capacity. (determined)
	Mfd	ohms	ohms	Mfd
Siemens and Halske, 1 Microfarad.	·5 (*a*)	15,770	28	·5129
	·5 (*b*)	16,330	28	·4957
	1·0	7,600	28	1·001
Siemens and Halske, 5 Microfarad, which was frequently used on alternating current circuits.	·5	17,000	28	·476
	1·0 (*a*)	8,300	28	·9709
	1·0 (*b*)	8,590	28	·9404
	2·5	3,275	28	2·453
	2·5 + 1·0 (*a*)	2,340	28	3·422
	2·5 + 1·0 (*b*)	2,360	28	3·393

Manchester Memoirs, Vol. xlviii. (1904), *No.* **12.**

XII. On the rate at which Ions are generated in the Atmosphere.

By ARTHUR SCHUSTER, Ph.D., F.R.S.

Received and Read March 1st, 1904.

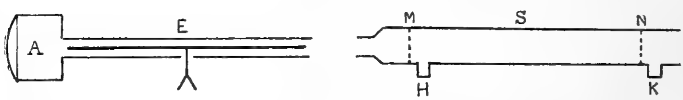
Two methods of measuring the ionization of the atmosphere are at present available. In the original experiments of Elster and Geitel, the dissipation of the electric charge of an insulated body was measured and the results obtained under different atmospheric conditions shewed that a closer investigation of the subject might lead to conclusions of considerable importance. But the dissipation of the charge of the electrified body depends on a variety of circumstances, and the observed changes in its amount are not easily interpreted. The second method devised by Ebert aims at measuring directly the number of ions in the air. Roughly speaking, these amount under ordinary conditions, and for each kind, to between two and four thousand per cubic centimetre. The positive and negative ions are always recombining, and if the total number remains approximately constant, this can only be due to the fact that a continuous process of regeneration is going on at the same time. Equilibrium is reached when the number generated equals the number recombining in the same time. The rate of recombination is found to depend on the amount of dust with which the air is charged, and also apparently on its humidity. If on a particular day, the number of ions is found to be particularly large, this may be because the rate of recombination is exceptionally slow, or the regeneration exceptionally quick. None of the measurements which so far have been carried out, attempt to decide between the two alternatives, and yet this is perhaps the most important question of all.

March 26th, 1904.

In a closed space it is not very difficult with delicate electrometers to determine the rate at which ions are formed, but observation shews that it depends on the nature of the material composing the enclosure, and it would be wrong to argue that the formation of ions in the free atmosphere is the same as that measured in a closed vessel.

The present paper deals with the description of a method of measuring the rate at which recombination takes place in a particular sample of air. When the ionic density (the number of ions per cubic centimetre) is known, the measurement allows us to calculate the rate at which ions are being produced.

The left hand portion of the accompanying figure



represents Ebert's apparatus in a diagrammatic form. *E* is a tube about 3 centimetres wide, and 40 centimetres long. *A* is a box containing a turbine driven by clock-work, which sucks air through the tube at the rate of 1·6 litres per second, giving a linear velocity for the air in the tube of 233 cms./second. An insulated rod runs along the axis of the tube *E*, and in connexion with the rod, the figure shews the aluminium leaves of one of the very beautiful electroscopes of Elster and Geitel's construction. If the rod is charged negatively, the air passing through the space forming a cylindrical condenser gradually discharges it, and provided the electric force is sufficiently strong, all the positive ions are given up to the rod. Knowing the volume of air passing in a given time, and the capacity of the condenser, the quantity of electricity given up to the electroscope is measured by the observed diminution of potential. A correction for the slight leak due to defective insulation having been applied, the ionic density is calculated. Ebert found that if we could separate all the positive and negative ions in the air, we should obtain under ordinary conditions between one half and one electrostatic unit of each kind in a cubic metre of air.

My addition to Ebert's apparatus consists of a tube *S*, 5 cms. wide and 60 cms. long, which can be pushed over Ebert's tube, so as to form a sufficiently air-tight joint. Two side tubes *H* and *K* are open at the bottom but may be closed by means of a cap. Inside one of the caps I place a small tube containing 5 mgms. of radium bromide enclosed in a short lead cylinder so that nearly all the radiation is upward. Observation shews that the direct effect of the radium on the electroscope is too small to affect the result. If the air sucked through by *A* passes over the radium in *H*, the strong ionization causes the potential of the electroscope to diminish by 100 volts. in about 15 seconds. If the radium is placed in *K*, the same diminution of potential requires the current to be maintained for about half a minute. The difference in the observed times for a given drop of potential measures the rate at which recombination has taken place while the air traverses the distance *HK* which, in the apparatus used, was 40 cms.

The rate at which positive and negative ions combine is proportional to the products of the ionic densities of each kind, so that if there are n ions per cc. of each kind present, and θ represents the time

$$\frac{dn}{d\theta} = -\alpha\, n^2$$

α is a constant which has been determined for dry dust-free air, and which with the help of this apparatus may be determined for ordinary air, by a method already employed by Rutherford, Townsend and others.

Integrating the above equation we find that if n_o be the ionic density at time θ_o and n_1 at time θ_1

$$\frac{1}{n_1} - \frac{1}{n_o} = a(\theta_1 - \theta_o) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Similarly at time θ_2

$$\frac{1}{n_2} - \frac{1}{n_o} = a(\theta_2 - \theta_o) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Imagine now the tube to be placed in *H* in the accompanying figure and the ionic density over a cross-section at *M* to be n_o; if n represents the density at a time that the ions pass within the condenser and are caught by it, equation (2) can be made to apply. Similarly in equation (3) n_o may represent the ionic density at *N* when the radium is placed in *K* provided *N* and *M* are taken at equal distances from *H* and *K* respectively. Subtracting the two equations we find

$$\frac{1}{n_2} - \frac{1}{n_1} = a(\theta_2 - \theta_1)$$

With the radium in *H* let the inner rod of the condenser fall from potential V_o to V in time t_1, and with the radium *K* let the same fall of potential take place in time t_2. Then if Q be the volume of air entering the apparatus in unit time the number of ions entering is Qn_1t_1 and Qn_2t_2 respectively, so that if e is the ionic charge and C the capacity of the condenser.

$$Qen_1t_1 = C(V_o - V_1)$$

and

$$Qen_2t_2 = C(V_o - V_2)$$

from which we find

$$a(\theta_2 - \theta_1) = \frac{1}{n_2} - \frac{1}{n_1} = Qe\frac{(t_1 - t_2)}{C(V_o - V_1)}$$

$\theta_2 - \theta_1$ is the time taken for the air to travel through a distance equal to that between *H* and *K*; hence if *d* be that distance and *U* the velocity of the air

$$a = Qe\frac{(t_1 - t_2)U}{C(V_o - V_1)d}$$

The ratio a e may thus be calculated if the velocity of the air current is known, and as e is known to be very approximately $3{\cdot}4 \times 10^{-6}$, α may be calculated.

Four observations taken during the last few days may serve as illustrations, but I do not attach great value to the actual numbers as I have had no opportunity yet of checking some of the constants of the instruments, and there is also some unexplained systematic difference depending on the quantity of radium employed in the measurement.

The places of observations are

R = A field near Rochdale. The observations having been taken on Sunday there was no smoke from factory chimneys.

O = Flat roof by the side of the Observatory on the top of the buildings of the Physical Laboratories.

S = A large room (36 × 24 feet) on the ground floor of the Laboratory.

The value of α for dust-free air was determined with the same apparatus to be $1{\cdot}1 \times 10^{-6}$ for dust-free fairly dry air, agreeing closely with Townsend's value.

Date.	Place.	Weather.	α.	n.	m.
Feb. 28/04	R	Snowing at intervals, with spells of sunshine. East wind......	$3{\cdot}28 \times 10^{-6}$	2370	18·4
,, 29/04, morning	O	Cold — bright — gusty. East wind............	2·96	3600	38·5
,, 29, afternoon...	O	Cold—dull. East wind...	2·86	3660	38·3
,, 29	S	——	2·14	2370	12

The column n gives the ionic density observed when the apparatus was used with S attached to it. The last column gives an^2 which is the number of ions generated or recombining in one second of time when an equilibrium is reached with n as the total number.

It is interesting to notice that although Ebert's apparatus gives exactly the same total number n for the ionic density, in the open air at Rochdale and inside the Physical Laboratory, yet the conditions were evidently quite different as is seen from the value of m in the last column. It is also worth noting that both a and n were different in the morning and afternoon observations taken on the roof of the laboratory, but that m is practically unaltered.

Manchester Memoirs, Vol. xlviii. (1904), *No.* **13.**

XIII. Mean Tones, Equal Tempered Tones, and the Harmonic Tetrachords of Claudius Ptolemy.

By R. C. PHILLIPS.

(Communicated by C. W. Sutton, M.A.)

Received March 2nd. Read March 29th, 1904.

The harmonic, or enharmonic systems of music of the ancient Greeks are considered by many writers to belong to an order of melody long extinct; though there is abundant evidence to show that the present scale of the Arabs is a direct survival of that of classical times. This, the modern Damascus scale, as explained by the learned Michail Meshaq'ah, is intended to consist of twenty-four equal quarter-tones in the octave; and his arithmetical and geometrical constructions show how a canon, or monochord string can be thus divided with considerable accuracy.

The equal division of the octave is referred to by Aristides Quintilianus, as being probably the most "consonant," (that is, suitable) could it be attained; and this writer of the first or second century, A.D., describes melodic progressions on the then enharmonic scale of precisely the same nature as those now found in modern Arabic music. He mentions that the Pythagoreans divided the octave into twenty-four "dieses," but these were certainly not all equal; they constitute, however, the first attempt to divide the octave into twenty-four approximately equal intervals.

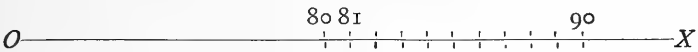
The system of Aristoxenus is often cited as a solution of the problem by ear. This is an error which is inconsistent with the words of Aristoxenus; and which an acquaintance with Claudius Ptolemy's writings would render impossible.

All the existing evidence tends to show that the enharmonic of Aristoxenus is identical with that of Eratosthenes, of the so-called pseudo-Euclid, and of Aristides himself. It thus appears that the Pythagoreans, the Alexandrians, and later mathematicians have attempted the problem how best to divide a canon, lute, or guitar fretboard into twenty-four practically equal quarter-tones, with varying degrees of success. Among all known writers, whether ancient or modern, who has solved the question with the nearest approach to mathematical accuracy? Beyond comparison, Claudius Ptolemy! But he has not revealed his intentions, and so far as is known none have guessed the meaning of his harmonic tetrachords, which have come down through seventeen centuries as an insoluble enigma.

The assertion that mean and equal tempered tones can be marked off on a canon or monochord by means of the harmonic tetrachords of Claudius Ptolemy, with a degree of accuracy never attained by other means, is capable of very easy proof. This in itself would be a strong argument that the tetrachords were designed for the purpose in question; but many would be inclined to doubt whether Claudius, in the absence of modern mathematical tables and methods, could be acquainted with the ratios of the intervals with the accuracy requisite to found on them the appropriate geometrical constructions.

Instead of adopting the short, modern methods, it is therefore preferable to make use of a longer, but more elementary, more easily intelligible demonstration, founded on the reasoning of the Pythagoreans. This deals with the section, or marking off, of a canon string in units of length; such units being subdivisible at pleasure so long as the respective ratios are maintained. It will be well to divide the subject into separate propositions, as under:—

To find the ratio of the Mean Tone.



Let *O X* represent a canon string; consider the divisions between 80 and 90. The points give the ratio 8 : 9 (by dividing by their difference, which does not affect the ratio) that is, the *tone*, or major tone. The lengths 81 to 90, by dividing by their difference, give the ratio 9 : 10, the minor tone. Hence we can go from 90 to 81, or from 90 to 80, so describing a minor or a major tone, with theoretical accuracy. But the mean of these, the half way between the major and minor tones, would be found by dividing the extra step, 80, 81 into two equal *intervals*; this can be very nearly done by halving the *intercepted distance* on the canon, and so calling $80\frac{1}{2}$ to 90 the mean tone. Doubling these numbers, to avoid the fraction, we get for the ratio of the mean tone 161 : 180. I shall show that one of Claudius's harmonic tetrachords enables us to arrive at these very numbers in another way.

To find the ratio of the Equal-tempered Tone.

It has been proved by Archytas that six tones (untempered) are equal to an octave and a comma of Pythagoras; therefore in order to temper, or compress, six tones into the limit of an octave, each tone must be curtailed by one sixth of the Pythagorean comma. The ratio of this comma was accurately known; it is very nearly 73 : 74. If, then, these lengths be marked off on a canon, the ratio will be sufficiently exact. Let this intercept be subdivided into six equal parts; multiplying by 6 to reduce it to sub-units we have:—

438, 439, 440, 441, 442, 443, 444.

These being equal units of length, the six intervals decrease slightly as the string is lengthened; the first being larger than the mean, the last smaller; on the whole the step 440, 441 will be extremely near to the one-sixth of the Pythagorean comma.

Now as 440 is a multiple of 8, we can denote the ratio 8:9 as 440:495; and, cutting off 440:441, the remainder, 441:495, is the equal tempered ratio required. It reduces to 49:55 on division by 9. I shall show that the other of Claudius's harmonic tetrachords enables us to arrive at these very numbers in another way.

The Harmonic Tetrachords of Claudius Ptolemy.

In his first book, Claudius mentions and comments on several systems of older writers, in the diatonic, chromatic, and enharmonic (otherwise harmonic) genera; the smallest subdivision of any being the ratio 40:39, which there is good reason to believe is somewhat too small for a melodic step. The smallest intervals so used were probably about a quarter of a tone, say 36:35; anything smaller being only added on to or subtracted from other intervals, not taken alone. Thus were formed the "three quarter" and "five quarter" tones mentioned by Aristides Quintilianus; which still exist in Arabic music. Hence such a ratio as 46:45 cannot represent a melodic interval, but must be a something to augment or diminish some melodic step of considerably greater magnitude. Much more must this be the case with the ratio 56:55.

In the Book mentioned, Claudius develops a system of tetrachords of his own invention, and adds the toniac of Archytas, thus giving three diatonic, two chromatic, and one harmonic tetrachord. It is this last only which here concerns us. His reasons for the section are a mystery to Dr. Wallis, his translator; his method is as follows:—

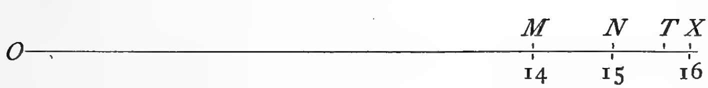
After dividing the ratio of the fourth, 4 : 3, into the two, 5 : 4 and 16 : 15, he triples the last numbers, giving 45, 46, 47, 48. He rejects 47, because it does not yield a "superparticular" ratio with the extremes, and so selects 45, 46, 48, or $\frac{46}{45}$, $\frac{24}{23}$, for the division of 16 : 15; placing the smaller interval at the grave extremity. Thus the complete section is denoted by the tetrachordal formula:—

$$\frac{46}{45} \times \frac{24}{23} \times \frac{5}{4} = \frac{4}{3}$$

Now one prominent member of his diatonic tetrachords is the ratio 8 : 7, which is about a minor tone and a quarter; let us examine the effect of curtailing it by the interval 46 : 45. We have at once:—

$$\frac{8}{7} \times \frac{45}{46} = \frac{4 \times 45}{7 \times 23} = \frac{180}{161},$$

the numbers already obtained for the mean tone. Hence follows the construction:—



Let *OX* be a straight line, not necessarily a canon string, divided into 16 equal parts, of which it is only necessary to consider *M*, *N* and *X*, situate at 14, 15, 16 severally. Then *MX* corresponds to the ratio 16 : 14, or 8 : 7; *NX* to 16 : 15.

NX has now to be divided in the point *T*, such that

TX represents 46:45. Then *M T* will be a mean tone. The point *T* can be determined geometrically by interpolating two harmonic means between *OX* and *ON*; arithmetically by dividing *NX* into 23 equal parts, and taking 8 from the end. For the numbers 15, 16, thus treated, give 345, 368; and taking 8 from 368 we have 345, 360, 368, which are in the required ratios: 23:24 and 45:46.

In the second Book, without a word of explanation, this harmonic tetrachord is replaced by another form :—

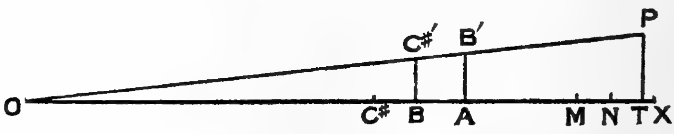
$$\frac{56}{55} \times \frac{22}{21} \times \frac{5}{4} = \frac{4}{3}$$

to the still greater mystification of Dr. Wallis. Treating the interval 8:7 as before, but with this new factor, we have

$$\frac{8}{7} \times \frac{55}{56} = \frac{55}{49}$$

the numbers already obtained for the equal tempered tone. The construction turns out to be simpler than before; keeping to the last figure it is only necessary to divide *NX* into 7 equal parts, and to take two from the end. For, multiplying 15, 16 by 7, we have 105, 112; and deducting 2 there result 105, 110, 112, which are in the ratios 21:22, 55:56.

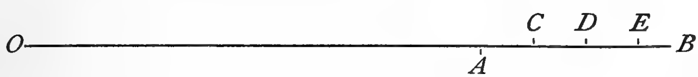
This last section provides the means for dividing an octave into six equal tempered tones.



Let the letters of this figure have the same signification as before, *M T* being an equal tempered tone. Draw *P T* equal to *M T* and at right angles thereto. Join *P O.*

If now OA be the actual length of a canon string, draw AB' at right angles, meeting OP in B'. Cut off AB equal to AB'. Then AB will be an equal tempered tone. From B draw in like manner $BC\sharp'$, and cut off $BC\sharp$ equal to $BC\sharp'$. $BC\sharp$ will be another equal tempered tone; and so on. The sixth tone so described will halve OA with an error of less than one part in 14,000. The straight line OP may be called the "line of tones," equal tempered, be it understood.

These tones can be subdivided into semitones and quarter tones of almost equal accuracy by means of the following principle, well known to the Pythagoreans. Let, in the following canon,



AB represent a small interval, such as a tone. Divide the intercept AB into four equal parts, $ACDEB$. Then the *interval* CE will be very nearly half of the *interval* AB. Hence a line of semitones can be found by erecting a perpendicular from E, equal to CE, and joining its extremity with the point O; thus the six tones can be bisected; and so likewise the semitones for quarters. Testing this theorem by the tone 9 : 8, we have the ratios 32 : 33 : 34 : 35 : 36; of which we take 33 and 35.

$$\text{Now } \frac{35}{33} \times \frac{35}{33} = \frac{1225}{1089}$$

which differs from $\frac{9}{8}$ by one part only in 9800. In any case the errors of actual marking and adjusting the divisions of the canon far exceed the theoretical errors of the above sections, which, consequently, cannot be improved.

The scope of the title of this paper has now been fully covered; it has been shown that the mean and the equal tempered tone can be easily described by means of these tetrachords; and no other reason for their invention can be assigned. Moreover, from the manner of reasoning of the Pythagoreans it is extremely probable that the calculation of these ratios would present no difficulty to Claudius Ptolemy, did he turn his attention to the matter.

Lastly, it is so highly improbable as to be a "moral impossibility" that he should, by chance, hit on the solution of these interesting and important problems. Hence it seems an irresistible conclusion that the equal tempered scale was first invented or perfected by Claudius Ptolemy of Pelusium in the second century, A.D.

Manchester Memoirs, Vol. xlviii. (1904), *No.* **14**.

XIV. The Constitution of the Ammonium Compounds.

By JOHN CANNELL CAIN, D.Sc., M.Sc.

(Communicated by Professor H. B. Dixon, F.R.S.)

Received March 12th. Read March 29th, 1904.

The theory of ammonium compounds, proposed by Ampère in 1816 and generally accepted even at the present time has not, in spite of its continuance, been entirely free from attack.

The objections of Kekulé, based on his non-belief in the existence of a pentad nitrogen atom, cannot, of course, be regarded as valid to-day as the doctrine of variable valency is everywhere accepted.

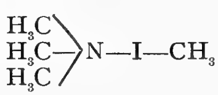
Thus Japp in the Kekulé Memorial Lecture, 1897, says "the doctrine . . . of fixed valency . . . is, so far as I am aware, without supporters."

We have long given up, therefore, Kekulé's molecular formula of ammonium chloride,

$$NH_3.HCl,$$

although we still adhere to this method of writing a large number of so-called molecular compounds.

The difficulty of explaining the union of ammonia and hydrochloric acid in terms of the ammonium theory was raised by Chevreul, and Wurtz (The Atomic Theory, 1880) found it hard to explain why the chlorine should give up its affinity for hydrogen, and unite with nitrogen for which it has only a slight attraction. He pointed out that although the separation of chlorine and hydrogen should give rise to a considerable absorption of heat, and the union of chlorine and nitrogen can produce only a feeble evolution of heat, yet the formation of sal-ammoniac gives rise to a considerable evolution of heat. Wurtz's explanation of this is that "the affinity of the chlorine for "hydrogen is satisfied by the attraction which it exercises "upon all the atoms of hydrogen within the sphere of "which it is now situated." This, however, goes beyond the confines of the valency theory. The inability of the ammonium theory to explain the extraordinary stability of tetramethyl ammonium iodide to caustic potash has been pointed out by Armstrong in 1888 (*Phil. Mag.* [5], **25**, 21), and also in his article "Chemistry" in the *Encyclopædia Britannica.* He says, "It is highly remark-"able that tetramethyl ammonium iodide should not be in "the least affected by even the strongest caustic alkali, "and that the halogen . . . behaves much as does that "in alkylic haloids. This would seem to be a strong "argument in favour of the view that the halogen is not "simply associated with the nitrogen, but retained in "combination with the hydrocarbon radicle." Armstrong suggested (1888) that this substance should be represented by his "residual affinity" formula



An important objection to the ammonium theory has quite recently arisen in the existence of isomeric optically inactive organic ammonium salts. Werner (*Annalen*, 1902, **322**, 261) instances the two isomeric trimethyl iso-butyl ammonium salts of Le Bel (*Comptes Rendus*, **110**, 144), the two methyl di-ethyl amyl ammonium chlorides of Schryver (*Chem. News*, 1891, **63**, 174), and the ethylene propylene dipiperidinium bromides of Aschan (*Ber.*, 1899, **32**, 988). Aschan, however, has contradicted the existence of the latter (*Ber.*, 1903, **36**, 1164), and the other two cases may be attributed to dimorphism. (cp. Jones, *J. C. S.*, 1903, **83**, 1401). There are still the isomeric inactive phenyl benzyl allyl methyl ammonium iodides of Wedekind (*Ber.*, 1899, **32**, 518), one of which has been resolved into its optically active constituents by Pope and Peachey (*J. C. S.*, 1899, **75**, 1127), and the several sets of isomers described by Kipping (*J. C. S.*, 1900, **77**, 861. 1901, **79**, 430. 1903, **83**, 873), which are well defined. The latter has obtained two isomers of hydrindamine bromocamphorsulphonate, chlorocamphorsulphonate and cis-π-camphanate as well as others from substituted hydrindamines, none of which contain an asymmetric nitrogen atom. The existence of such isomeric forms recalls the experiments of V. Meyer and Lecco (1876) who showed the identity of the quaternary ammonium iodides obtained from trimethylamine and ethyl iodide and ethyl dimethylamine and methyl iodide, and concluded that this compound was properly represented by the ammonium theory and not to be regarded as a substituted ammonia hydrochloride. This conclusion must now be doubted in view of the many cases of two isomers here quoted.

Werner proposes a new ammonium theory which, involving as it does such terms as "Principal Valency" ("Hauptvalenz"), "Supplementary Valency" ("Nebenvalenz"), and "Co-ordination Constant," is apparently not very different from the older idea of molecular attraction or residual affinity. According to Werner, the formula of ammonium chloride would be

$$H_3N.........HCl,$$

a supplementary valency (indicated by the dotted line) existing between the nitrogen atom and the hydrogen of the hydrochloric acid; an assumption for which there is at present no experimental evidence.

The constitution which I suggest for the ammonium compounds would, I believe, account in a very simple manner for the whole of the facts referred to above, and the formulæ for ammonium chloride and ammonium hydrate would be

$$H_3N = ClH,\ H_3N = OH_2,$$

in which chlorine is triad and oxygen tetrad. The statement that, in the case of a pentavalent nitrogen atom, only four valencies can attach themselves to an organic radical, the fifth being always united to a halogen or hydroxyl group (cp. Vaubel, *Stereochemische Forschungen*, 1899; Wedekind, *Zur Stereochemie des fünf wertigen Stickstoffes*, 1899) is at once explained in the light of this formula. It is perhaps hardly necessary to adduce evidence in favour of the conception of triad chlorine. Thus Armstrong writes (*Encycl. Brit. loc. cit*): "As it is clear that iodine may exercise triadic functions, "the remaining halogens can scarcely be denied the rank "of potential triads"; and, again, Ramsay says (*Modern Chemistry*): "It must . . . be assumed that the halogen "atoms are . . . possibly triads." "The mode of com-"bination of these double salts (*i.e.*, $ZnCl_2 . 2KCl$) is "possibly owing to the fact that the halogens are capable "of acting as triads." That oxygen can often become tetravalent is to-day generally accepted.[1]

The union of ammonia and hydrochloric acid is very simply explained by the equation

$$H_3N + ClH \rightarrow H_3N = ClH.$$

The influence of moisture on this combination is, in my opinion, the same as in the case of the union of carbon monoxide and oxygen where there is no question of

[1] Although, as I find, these formulæ occur, together with corresponding ones for tetramethylammonium iodide and tetraethylphosphonium iodide in a paper by Heyes on Valency (*Phil. Mag.*, 1888 [5], **25**, 297), yet no arguments are used in favour of them, and no further application of them is made.

ionisation, or possibly intermediate addition compounds are formed with water by both ammonia and hydrochloric acid. The electrolytic dissociation of sal-ammoniac and ammonium hydrate is quite in accordance with the new formula. Whereas according to the usual ammonium theory, ammonium hydrate should dissociate in the same way as potassium hydrate,

$$NH_4 . OH = \overset{+}{N}H_4 + \overset{-}{O}H.$$

As a matter of fact the degree of dissociation is exceedingly small, resembling that of water, and Hautzsch has shown (*Zeitschr. für Phys. Chem.*, **30**, 258) that the dissociation takes place in the sense that water is split off. This is to be expected if we write

$$H_3N = OH_2 \rightarrow H_3N + H_2O.$$

The almost complete electrolytic dissociation of sal-ammoniac in dilute solution is equally well explained by both theories, thus we have

$$NH_4Cl = \overset{+}{N}H_4 + \overset{-}{C}l,$$

and

$$(1)\ H_3N = ClH \rightarrow H_3N + HCl.$$
$$(2)\ HCl \qquad = H \quad + Cl,$$

we get here a complete ion $\overbrace{NH_3 . H}^{+}$, and there is, of course, no evidence as yet which can decide between the ion $\overset{+}{N}H_4$ and the more complex one $\overbrace{NH_3 . H}^{+}$.

The remaining halogen salts of ammonia are analogously written, and the sulphides thus—

$$H_3N = \overset{IV.}{S}H_2 \text{ and } (H_3N)_2\overset{VI.}{S}H_2.$$

My formula for ammonium hydrate

$$H_3N = OH_2$$

is analogous to that of water $H_2O = OH_2$, of hydrogen peroxide $O = OH_2$, and of ozone $O = O = O$. The general formula for salts of ammonia and oxygen acids is

$$H_3N = OHX,$$

thus ammonium sulphate is written

$$H_3N = \underset{\dot{H}}{O} - SO_2 - \underset{\dot{H}}{O} = NH_3,$$

oxygen, of course, being tetrad.

The obvious question as to the possibility of this formula, in view of the isomorphism of the ammonium and potassium salts, at once arises. Ought we not, however, to expect some difference between these salts from the fact that water is always eliminated in the formation of, for instance, potassium sulphate, while no such reaction takes place in the case of ammonium sulphate? The formation of potassium sulphate may, however, be exactly analogous to that of ammonium sulphate, thus—

(1) Addition,

$$2KOH + H_2SO_4 \rightarrow H\overset{K}{\dot{O}} = \overset{H}{\dot{O}} - SO_2 - \overset{H}{\dot{O}} = \overset{K}{\dot{O}}H.$$

(2) Molecular change,

$$H\overset{K}{\dot{O}} = \overset{H}{\dot{O}} - SO_2 - \overset{H}{\dot{O}} = \overset{K}{\dot{O}}H \rightarrow H\overset{H}{\dot{O}} = \overset{K}{\dot{O}} - SO_2 - \overset{K}{\dot{O}} = \overset{H}{\dot{O}}H.$$

(3) Water split off,

$$H\overset{H}{\dot{O}} = \overset{K}{\dot{O}} - SO_2 - \overset{K}{\dot{O}} = \overset{H}{\dot{O}}.H \rightarrow \overset{K}{\dot{O}} - SO_2 - \overset{K}{\dot{O}} + 2H_2O.$$

In the case of ammonium sulphate, the group attached to the tetrad oxygen atom is split off at a higher temperature.

If we have hitherto regarded as isomorphous, compounds containing two such differently constituted groups as

$$X - O - K \text{ and } X - O - N \begin{array}{l} H \\ H \\ H \\ H \end{array}$$

can we say that the groups

$$X-O-K \text{ and } X-\overset{\diagup H}{O}=NH_3$$

would not belong to isomorphous salts?

Lothar Meyer says (*Outlines of Theoretical Chemistry*) "it has been assumed that an atom of potassium can be "isomorphously replaced by the 'compound radical' "ammonium, composed of one atom of nitrogen and four "atoms of hydrogen; but if this is possible in one case, "it may frequently happen that several atoms replace one "single atom. If we admit this, then *the whole foundation "of these considerations* (*i.e.* on isomorphism) *is weakened*" (the italics are mine). We must also not forget that the nitrates, the bichromates, and the persulphates of potassium and ammonium are not isomorphous. There is thus no argument from the theory of isomorphism which negatives my view.

The constitution of the metal-ammonium compounds is sufficiently indicated by the formulæ

$$H_3N=ClAg, \quad H_3N=ClCu, \quad H_3N=ClPtCl=NH_3$$

for the compounds of ammonia with the chlorides of silver, copper, and platinum respectively.

The correctness of this theory is rendered the more probable by the ease with which it explains the existence of the isomeric quaternary ammonium salts to which reference has already been made. The stereochemical configuration of ammonium chloride and its substitution products, according to the usual ammonium theory, presents a special difficulty, owing to the fact that no symmetrical solid geometrical figure with five corners exists. In order, therefore, to arrive at a space formula, it became necessary to assume that certain valencies attached to the nitrogen atom are arranged in special directions. This is obviously a very grave assumption, and one which, of course, has no parallel in the very simple configuration of the carbon atom. In this way has been developed the cubic formula of van't Hoff, the double tetrahedron of Willgerodt and the square pyramid of Bischoff. If we, however, accept the formula which is here presented, no new assumption has to be made in order to arrive at a space configuration. The nucleus N = Cl, instead of a carbon atom, is supposed to be at the centre of a tetrahedron, and we have

$$-\overset{|}{\underset{|}{N}}=Cl- \text{ corresponding to } -\overset{|}{\underset{|}{C}}-$$

The number of possible isomers is shown by the following table :—

General formula.	Number of isomers.	Formulæ of isomers.
NAAAACl	1	$A_3N = ClA.$
NAAABCl	2	$A_3N = ClB \,.\, A_2BN = ClA.$ (1)
NAABBCl	2	$A_2BN = ClB \,.\, AB_2N = ClA.$
NAABCCl	3	$ABCN = ClA \,.\, A_2BN = ClC \,.\, A_2CN = ClB.$
NABCDCl	4	$BCDN = ClA \,.\, ACDN = ClB \,.\, ABDN = ClC \,.\, ABCN = ClD.$ (2)

The corresponding formulæ for acids other than hydrochloric are easily written.

The formula for tetramethylammonium iodide, viz.,

$$(CH_3)_3N = ICH_3$$

(1) These would be the formulæ of Kipping's hydrindamine salts (*loc. cit.*)

(2) Three of these have been prepared in the case of the Phenyl methyl allyl benzyl ammonium iodides ; two optically active (Pope and Peachey, *loc. cit.*) and one inactive (Wedekind, *loc. cit.*).

also explains its reactions much better than does the usual one (c.p. Armstrong).

The fact that a comparatively small number of isomers indicated by the above formulæ exists, is to be expected, for the isomers would in many cases differ greatly in stability. There would be a "stable" and a "labile" form, and often the labile would pass into the stable form so quickly as to prevent its isolation.

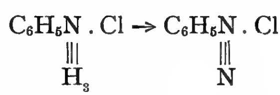
The ammonium theory has been freely used in the past in order to arrive at a formula for analogously constituted bodies, thus we have the phosphonium, arsonium, stibonium, sulphonium, oxonium, and diazonium compounds. We should, in view of the new theory, write the general formulæ

$$H_3P = ClH, \; H_3As = ClH, \; H_3Sb = ClH, \; H_2S = ClH, \; H_2O = ClH$$

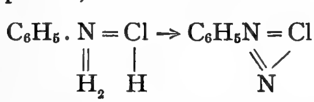
corresponding to

$$H_3N = ClH.$$

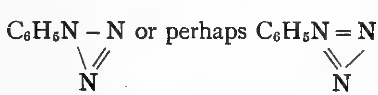
The diazonium salts which are now considered to be derived from, *e.g.*, aniline hydrochloride by the replacement of three hydrogen atoms by one nitrogen, thus



a mode of representation which does not account for the explosive nature of these compounds would be better written, in my opinion, as follows:



resembling the formulæ of the azoimides

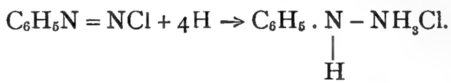


This mode of representation of the diazonium salts resembles both the older formula of Kekulé and the later one of Blomstrand in several important respects.

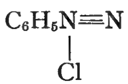
In Kekulé's formula,

$$C_6H_5 . N = N . Cl,$$

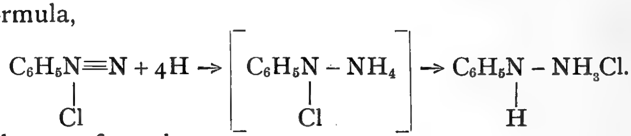
the double linking between the nitrogen atoms shows a close analogy to the azo compounds, and the position of the chlorine atom easily explains the formation of hydrazines thus,



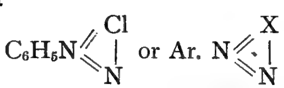
The Blomstrand formula, on the other hand,



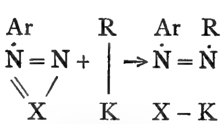
shows the presence of pentad nitrogen, and is analogous to the existing ammonium theory. It is difficult, however, to explain the reduction to hydrazine by this formula,



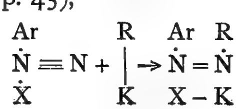
The new formula



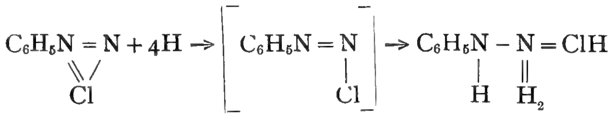
explains the transition of a diazonium salt into a *syn*-diazo compound thus,



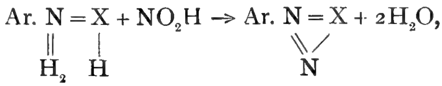
avoiding the change of linkage necessary according to Hautzsch (*loc. cit.*, p. 45),



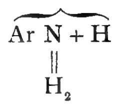
and provides an easy representation of the hydrazine formation



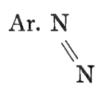
The diazotisation process is written



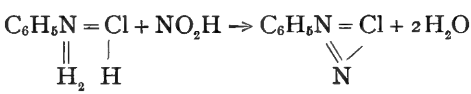
the complex ion



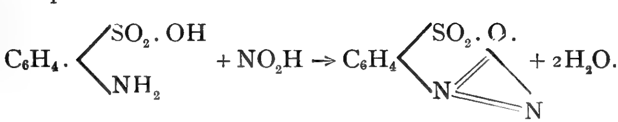
being transformed into the ion



thus in the case of aniline we have



and sulphanilic acid



The other reactions of diazonium salts, as well as those of the phosphonium, arsonium, etc., compounds, are similarly written.

MUNICIPAL TECHNICAL SCHOOL,
BURY, LANCASHIRE.

Manchester Memoirs, Vol. xlviii. (1904), *No.* **15**.

XV. Notes on some Polyclad Turbellaria in the British Museum.

By F. F. LAIDLAW, B.A. (Cantab.)

Received and Read March 29th, 1904.

PLANOCERIDÆ.

PLANOCERA PELAGICA (Moseley).

Stylochus pelagicus, Moseley ['77].

Planocera pelagica, Lang ['84].

Stylochoplana sargassicola, von Graff ['92] (partim).

Three specimens, collected "from February 28th to March 5th, 1889. Surface of N. and S. Atlantic, and from Cape [of Good Hope?] to Australia. Capt. Carvasso."

This is the smallest species of the genus with the exception of *Pl. simrothi* which is of about the same size with it. There can be no doubt that this species is a true *Planocera* closely allied to *Pl. pellucida* but distinctly smaller and with differently arranged eye-spots.

The length of the three specimens in the collection ranges from 8 to 10 mm. and the breadth from 5 to 7 mm. In Moseley's figure 11 ['77, *pl.* III.] *MG* is really, I think, the female opening whilst *FG* is the opening of the non-muscular part of the vagina into the muscular part or bursa copulatrix.

The species is quite distinct from *Stylochoplana sargassicola.* (Mertens)

It would be interesting to compare its distribution with that of *Planocera pellucida.* The latter appears to have a very wide range, whilst *P. pelagica* is perhaps confined to the Atlantic.

STYLOCHIDÆ.

STYLOCHINÆ.

Genital openings close to each other and to the hinder end of the body. Penis without stylet. Tentacles and marginal eyes present. The prostate frequently has its walls strongly folded. [:03 *a.*]

STYLOCHUS VIGILAX, sp. n.

"Beach. Thursday Id. H.M.S. 'Alert,' 26-10-81." One specimen.

Length about 35 mm. Breadth 22 mm.

A *Stylochus* with marginal eyes on the anterior part of the margin only. Ovaries dorsal, genital openings separated but very close to each other, about 0·15 mm. apart and about 4 mm. from the hinder end of the body. A peculiarity of this species is the complete absence of any muscular vesicula seminalis. Where the two vasa deferentia unite there is a feeble dilatation but its walls are no more muscular than those of the vasa deferentia themselves.

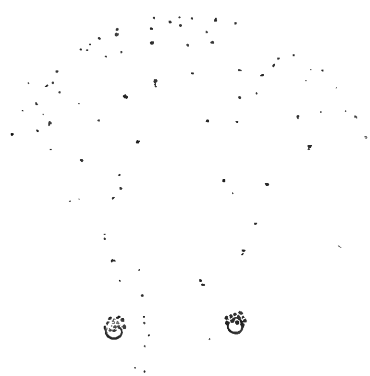


FIG. 1.
Stylochus vigilax × 4.

The cluster of eye-spots at the base of either tentacle is rather denser than in most species of the genus. These eyes are considerably larger than those lying over the brain or about the anterior margin. (See *Fig.* 1.) The dorsal epidermis contains large numbers of the "Schleimstäbchen" which are characteristic of the genus. As in other species the walls of the prostate are strongly folded.

LEPTOPLANIDÆ.

LEPTOPLANA AUSTRALIS, sp. n.

"Port Phillip. Presented by Dr. R. v. Lendenfeld." Six specimens.

Dimensions of the largest specimen. Length about 30 mm. Breadth about 15 mm.

The arrangement of the eye-spots is shown in the accompanying text-figure (see *Fig.* 2). Colour a dark

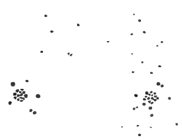


FIG. 2.
Leptoplana australis × 3.

chocolate-brown, deepest on the margin, ventral surface rather lighter. Two of the specimens have lost their colour to a great extent. Penis armed with a long, nearly straight stylet, about 2 mm. in length, directed backwards and downwards. Prostate divided into some six or seven longitudinal chambers. The lower part of the vagina is modified to form a large muscular bursa copulatrix. One of the specimens shows distinctly traces of nuchal tentacles. I believe that *Leptoplana alcinoi*, an allied species, occasionally exhibits a similar feature.

LEPTOPLANA DRŒBACHENSIS, Oersted.

Leptoplana drœbachensis, Lang ['84], Jensen ['78], Gamble ['93].

"Godthal. Mr. Holböll's collection. 60 faths." One specimen.

The external features and as much of the anatomy as could be determined from the inspection of a specimen cleared in cedar oil agreed closely with the specimen so beautifully figured by Jensen ['78]. I cut serial sections through the genital tract; these have revealed the following points of interest. The prostate gland is divided up longitudinally into about twelve chambers. The vagina is not developed into a bursa copulatrix, and the accessory parts are without muscular walls. These accessory parts consist of a duct, which Jensen described as having a curious moniliform appearance; the accessory duct, and a large accessory vesicle. The cells lining the duct form here and there little glandular 'bunches' or clusters of cells on either side of the duct, which in their neighbourhood has its lumen much contracted. It is no doubt their presence which gives the accessory duct its moniliform appearance. The walls of the accessory duct are but poorly furnished with muscle fibres. The 'bunches' consist of small pear-shaped darkly staining cells, with rather large nuclei. The smaller ends of these cells project into the lumen of the duct.

The accessory vesicle is also only feebly muscular, it is lined with columnar secreting cells, which recall in appearance to some extent those of the receptaculum seminis of *Paraplanocera.* The shell glands *lie about the accessory vesicle.*

It is evident, I think, that this species is closely related to *Leptoplana nationalis* described by Plehn ['96]. I am not able to determine whether the relative extent of the main-gut is the same in the two species as the specimen of *L. drœbachensis* at my disposal is very much contorted. Plehn's specimen however differs markedly in having thick muscular walls to the accessory vesicle of the vagina.

In a previous paper [:**03**] I attempted to arrange the sufficiently known species of *Leptoplana* according to certain characters which can readily be determined. The two specimens already noted in this paper both belong to the division of the genus in which the penis is armed with a stylet. Their places in this division are indicated in the amended table given below.

A. Penis provided with a stylet
- (*a*)
- (*b*) Prostate divided into longitudinal chambers.
  - (*α*) Lower part of vagina very muscular, forming a bursa copulatrix.
    - (i.) Stylet extending the whole length of the penis.
      - *L. vitrea.*
      - *L. australis.*
    - (ii.) Stylet not more than half the length of the penis
      - *L. alcinoi.*
  - (*β*) Lower part of vagina not very muscular, no bursa copulatrix present.
    - *L. drœbachensis.*
    - *L. nationalis.*

CRYPTOCELIDIDÆ.

CRYPTOCELIDES LOVENI, Bergendal.

Labelled "J. B. Wilson, 88-1-27, Port Phillip." I imagine that there must be some error in the locality given for this specimen. I have in my possession a single specimen from the Firth of Clyde dredged in 10 fathoms.

In concluding I wish to thank Professor Hickson for permission to carry on my work in the Zoological Laboratories of the Manchester University.

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Manchester Memoirs, Vol. xlviii. (1904), *No.* **16.**

XVI. Note on the Union of Hydrogen with Sulphur, Selenium and Tellurium.

By Francis Jones, M.Sc., F.R.S.E., F.C.S.

Received and read April 12th, 1904.

The direct union of hydrogen with sulphur has been investigated by many chemists and repeatedly affirmed. At the end of the eighteenth century Scheele stated that when sulphur was heated to the subliming point in an atmosphere of hydrogen, or when hydrogen was passed over melted sulphur, combination took place between the two elements and that the volume of gas remained unaltered. This was confirmed by Corenwinder[1], Cossa[2], and by Merz and Weith[3], who found that sulphuretted hydrogen was formed abundantly by passing hydrogen through boiling sulphur, and Chevrier[4] obtained the same gas by passing induction sparks through a mixture of sulphur vapour and hydrogen. On the other hand Myers[5] finds that carefully purified hydrogen, when passed over boiling sulphur, yields mere traces of sulphuretted hydrogen and attributes the contradictory results of other chemists to the presence of hydro-carbons or moisture in the hydrogen they employed. Further, he found that sulphuretted hydrogen is decomposed at a temperature of 400°C. and concludes that its synthesis at the temperature of boiling sulphur is incredible.

It is impossible to reconcile these conflicting statements; hydrogen either combines directly with sulphur

[1] *Ann. der Chem. und Pharm.* vol. 84, p. 225.
[2] *Ber. Chem. Gesellsch.* 1868 p. 117.
[3] *Ibid* 1869 p. 341.
[4] *Compt. Rend.* vol. 69, p. 136.
[5] *Compt. Rend.* vol. 74, p. 195.

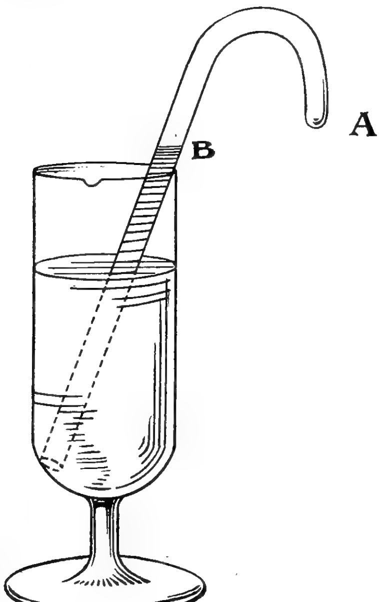
or it does not, and it seemed to me worth while to make some experiments to endeavour to settle the disputed point.

Hydrogen and Sulphur.

In the first experiment, carbonic anhydride, purified by being passed successively through water, sulphuric acid, fuming sulphuric acid, asbestos and phosphoric anhydride, was passed into a U tube containing purified sulphur which was kept boiling. The exit tube of the apparatus was so arranged that test papers moistened with solution of lead could be applied from time to time. At first these papers were considerably blackened by the action of the escaping gas, but this diminished in intensity, and when the apparatus had been in use for some days the alteration in the papers was scarcely appreciable and constant. When this minimum reaction was reached the gas evolution apparatus was changed for one evolving pure hydrogen, which was passed through the same drying apparatus. In a very short time the papers darkened rapidly, and when all the carbonic anhydride had been expelled by the hydrogen, the escaping gas smelt strongly of sulphuretted hydrogen and instantly blackened the test papers.

That the presence of moisture was sufficient to cause the blackening of the test papers was then shown by obtaining the minimum reaction as before with carbonic anhydride, and then inserting a wash bottle containing a few drops of water, just before the U tube containing the boiling sulphur. In a very short time the test papers were considerably blackened and large quantities of sulphuretted hydrogen were evolved.

This experiment shows the difficulty of removing every trace of moisture from a gas, and at the same time the importance of effecting that object, if the formation ot sulphuretted hydrogen is to be relied on as an indication that combination has taken place between hydrogen and sulphur. Another experiment was therefore devised in which the presence of water cannot interfere with the accuracy of the result: A bent tube having one limb longer than the other was obtained, the shorter limb was sealed up, the longer one was open. A piece of pure



fused sulphur was placed in the closed end at A and the tube filled with hydrogen by displacement, the open end of the tube meanwhile dipping in a solution of soda contained in a test glass as in the sketch. Before withdrawing the india-rubber tube which admitted the hydrogen, a small quantity of the gas was withdrawn by suction so as to raise the level of the liquid in the tube above that of the soda in the test glass as at B. The level of the soda in the tube was then marked and the sulphur heated to the boiling point. In a very short time afterwards it was found that the increase in volume of the gas, caused by the expansion, was overcome, and the soda rose steadily above the original level. Some hydrogen therefore had disappeared from the tube, and this can only be accounted for by supposing that it had united with the sulphur to form sulphuretted hydrogen which was absorbed by the soda.

In still another way the union of hydrogen with sulphur was shown. A piece of sulphur sealed up in a tube with hydrogen was heated for a short time in a bath of boiling sulphur.[1] When cold the point of the tube was broken under soda solution, which rose so as to fill the tube entirely. That the union of the two elements was accomplished without change of volume was shown by the slow entrance of the soda into the tube.

From these experiments it is evident that the chemists who have affirmed the synthesis of hydrogen sulphide from its elements have been correct in their observations. With regard to the temperature at which the reaction takes place, it was found to be very near to the boiling point of the sulphur. No combination takes place at the melting point, as has been affirmed, if the sulphur used is pure, but if roll sulphur (which always contains sulphuretted hydrogen) be employed that gas is given off at the beginning of the experiment.

Hydrogen and Selenium.

The readiness with which hydrogen unites with selenium has been long known. According to Ditte[2]

[1] See also Hautefeuille. *Compt. Rend.* vol. 64, p. 610 (footnote).

[2] *Compt. Rend.* vol. 74, p. 980.

the maximum quantity of seleniuretted hydrogen produced is a function of the temperature, and increases from 250°C. to 520°C., and then decreases regularly to 700°C. On trying the experiment in a bent tube similar to the one used for hydrogen and sulphur, I found that combination took place much more readily, and the solution of soda rose rapidly in the tube. The sodium selenide formed was found to be insoluble in soda of the strength used (1 part soda to 15 parts water), and crystallized out in beautiful needle-shaped crystals, sometimes over an inch in length. These have been investigated by Fabre,[1] who determined their composition, and found that the selenide crystallizes with different amounts of water depending on the strength of the soda and the temperature. Salts corresponding to the following formulæ have been obtained :

$$Na_2Se9H_2O,\ Na_2Se16H_2O,\ 2Na_2Se9H_2O,$$

and an anhydrous one, Na_2Se is obtained by heating any of the above in a current of nitrogen. These crystals are extremely unstable when removed from the soda solution. They become red in a few seconds owing to separation of selenium, and on exposure to air rapidly change to a mixture of sodium carbonate, selenium, and sodium selenite.

Hydrogen and Tellurium.

Tellurium also combines readily with hydrogen. When the experiment in the bent tube was made, using hydrogen and tellurium, the reaction took place in a precisely similar manner, but even more readily than when selenium was used. There was, however, no formation of sodium telluride crystals, either with soda of the same strength or when a stronger solution was used.

[1] *Compt. Rend.* vol. 102, p. 613.

Manchester Memoirs, Vol. xlviii. (1904), *No.* **17**.

XVII. On the Electrolytic Methods for the Detection and Approximate Estimation of Minute Quantities of Arsenic in Beer, Malt, and Food Stuffs, Etc.

By WILLIAM THOMSON, F.R.S.E., F.I.C.

Read December 15th. Received April 12th, 1904.

On the 3rd of March of last year I read a paper before this Society on the detection and approximate estimation of arsenic by the Marsh-Berzelius method. I now desire to place before you the results I have obtained by the study of the electrolytic processes.

During the sittings of the "Royal Commission "on Arsenical Poisoning arising from the consumption "of beer, and other articles of food or drink," the chairman, Lord Kelvin, suggested that an electrolytic method of liberating hydrogen might be devised which would remove the difficulty of providing arsenic-free zinc.

I felt that his lordship (who was very strong on the possibility of doing this) had not taken sufficiently into consideration the chemical properties of the element with which we had to deal, as I had previously tried an electrolytic method and failed to get anything like the required arsenical mirrors.

A Committee was appointed by the Commissioners of Inland Revenue, to suggest the best process and form of apparatus for the detection and estimation of arsenic in food and drink. The following were appointed members of the Committee :—

Dr. T. E. Thorpe, C.B., F.R.S.
Professor William Augustus Tilden, D.Sc., F.R.S.
Professor Harold Baily Dixon, M.A., F.R.S.
Graham Aldous, Esq.
John Pattinson, Esq., F.I.C.
With Mr. T. J. Cheater, of the Government Laboratory, as Secretary.

This Committee decided on the electrolytic method as the best, and they devised the ingenious little apparatus which was shown by Professor H. B. Dixon at the meeting at which I read my last paper. It consists of a conical shaped platinum band, perforated with holes, as the kathode suspended by the platinum wire which carries the current through the glass stopper of a small bell jar (open at the bottom). This jar stands inside a porous pot, with a narrow circular platinum band outside the porous pot as the anode; the glass stopper in this bell jar is provided with a glass tube and stop-cock for introducing the liquid to be tested into the porous pot, and with a tube for carrying the hydrogen with any arsenic which might be present to the heated narrow tube where the arsenic mirror is deposited. The porous pot, surrounded by the platinum circular anode, with glass bell inside, being set in a circular open glass vessel containing diluted pure sulphuric acid (1 of acid to 7 of water), that vessel being again placed in a considerably larger glass vessel containing water to moderate the heat caused by the cell resistance to the electrical current.

At my request Professor Dixon kindly lent me his electrolytic apparatus, and I have made a somewhat exhaustive series of tests with it in comparison with those obtained from the Marsh-Berzelius apparatus when using arsenic-free reagents, and with other forms of electrolytic appliances.

My first test with the Committee's electrolytic apparatus showed that it gave much better arsenic mirrors than I had obtained by the first electrolytic apparatus which I devised some time ago, and I felt that after all Lord Kelvin was probably on the right track when he so strongly advocated the electrolytic process.

I found however that it was impossible to get mirrors by the Committee's electrolytic apparatus when using arsenic in the form of trioxide beyond the $\frac{1}{300}$th of a grain of arsenic trioxide per gallon when working on 50 c c. of liquid, equal to a total quantity in the apparatus of 0·0023 milligramme of arsenic trioxide (As_4O_6), equivalent to 0·00177 m.g. of the element arsenic.

I must apologise for mixing the metric system with English weights and measures, but this seems necessary, as the English method which has been accepted is to speak of grains or fractions of a grain per gallon or per lb., whilst I have worked in the laboratory with the metric system. In all my experiments I have used solutions computed as containing fractions of a grain (per gallon) of (As_4O_6) whilst employing 50 c.c. of such solutions or its equivalent for the tests, as this quantity of beer or other liquid is the one I have found most convenient for working.

I devised an apparatus on the same lines as that of the Committee, but greatly increased the areas of the platinum anode and kathode, and, curiously enough, I obtained with them exactly the same sizes and intensities of mirrors as by the Committee's apparatus. This arrangement also failed to detect anything beyond the $\frac{1}{300}$th of a grain per gallon of As_4O_6 when working on 50 c.c.

The use of other metals than platinum as kathode.

Lead was first tried in fine sheet, and after getting rid of the arsenic which it originally contained, and which came off gradually for a long time, it was found that smaller quantities of arsenic could be detected with it than with the platinum kathode, but the results were irregular.

Copper also gave irregular results.

With aluminium and plumbago as kathode, the $\frac{1}{500}$th of a grain per gallon when using 50 c.c. of the solution gave no mirror.

Tin was tried, but I failed to get any of this metal free from arsenic, even after long continued passage of the current through it, If pure it might possibly form a satisfactory kathode.

Zinc as kathode.

A quantity of pure granulated zinc was put into the porous pot, and one of the pieces attached to the platinum wire which carried the negative electric current so that the granulated zinc constituted the kathode. This arrangement gave stronger mirrors for the different quantities of arsenic than the platinum kathode apparatus, but the mirror obtained with the $\frac{1}{1000}$th of a grain (when using 50 c.c.) was not equal to the standard produced from the Marsh-Berzelius method. The photograph of these mirrors is shewn in Series A *Fig.* 1, *Plate* VIII. The first tube in each series is a blank, made with the reagents alone, and they are all free from any trace of arsenic mirror, and as the photographs were taken with the illumination immediately above them, for the purpose of preventing the reflection of the glass from interfering with the photographs of the mirrors, those tubes which contain no arsenic mirrors are either seen with difficulty, or are invisible in the photographic prints: by following up, however, from the figures at the bottom, the positions of the tubes without mirrors can be fixed by the eye in each series, and I must also observe that the prints are not as accurate representations of the mirrors or their photographs as I should like, but they may be taken generally as approximately accurate as regards the intensities of the mirrors.

It occurred to me that as the presence of platinum in any form with the zinc always interfered with the delicacy of the test in the Marsh-Berzelius apparatus that it should be eliminated, so an apparatus was arranged with a rod of pure zinc as the kathode, and with this apparatus the electrolytic method was found to be as delicate as the Marsh-Berzelius process, and gave results in which the mirrors were rather more evenly deposited, and which has proved by continued experience to be reliable for the detection and approximate estimation of arsenic, whether it exists as arsenic trioxide (As_4O_6) or as arsenic pentoxide (As_2O_5), and so Lord Kelvin's suggestion has really given the best process for the approximate estimation of arsenic.

The Series B* *Fig.* 1, *Plate* VIII., shows the mirrors obtained by the Marsh-Berzelius method, and Series E and F show the mirrors obtained by the quantities indicated at the bottom when using my own zinc kathode electrolytic method, and cooling the part of the tube on which it was desired to deposit the mirrors; series E was obtained when using a current of 3 amperes, and Series F when using a current of 5 amperes. The former gives the mirrors less spread out than the latter, and I find it more easy to accurately compare mirrors obtained by a 3, than by a 5 ampere current. In some of the photographs of the mirrors obtained by the 3 ampere current there may appear not so much difference between the mirrors from two different quantities of arsenic; when, however, they

* All the prints of the tubes are about one half, or more accurately $\frac{5}{9}\frac{5}{8}$ths of the diameters of the originals.

are examined by an ordinary pocket lens, there can remain no doubt as to which is the greater, the relative densities of the two becoming then easy to discern. To determine the length of time required to eliminate all the arsenic, when working with my own electrolytic method, and when using respectively currents of 5 and 3 amperes, an apparatus was devised consisting of a three-way stop-cock ; the hydrogen from the electrolytic apparatus could thus be turned through a drawn out tube, heated and arranged for the deposit of the mirror at the right and at the left of the apparatus at will, without loss of gas from the apparatus. Each of these tubes was provided with an arrangement by which pure hydrogen was kept passing through it till required for the test, and the tube was also kept heated. The tubes were changed every 5 minutes, the arsenic coming off being deposited during 5 minutes in each tube. One-fiftieth of a grain of arsenic trioxide was dissolved in 1 gallon of liquid, and 50 c.c. of that liquid used for the test, and it will be observed by looking at *Plate* VII., *Fig.* 2, where photographs of the resulting mirrors are shown, that most of the arsenic is brought off during the first 15 minutes, when using 5 amperes, the remainder being brought away during the following 15 minutes, for during the seventh and eighth 5 minutes no arsenic was deposited. With 3 amperes the result was rather different, the arsenic was brought off in a steadily diminishing quantity till the seventh 5 minutes, no arsenic being shown during the eighth 5 minutes. It may be taken, therefore, that by working the zinc kathode electrolytic apparatus with 3 amperes, all the arsenic from any reasonable quantity, if present, would be removed from the apparatus, and deposited in the narrow tube within 40 minutes after introducing the suspected liquid. It is hardly necessary to mention that in every test it is necessary to work the apparatus with some pure dilute sulphuric acid before igniting the escaping hydrogen, and that the tube should previously be heated to redness in front of the drawn out portion on which the mirror is to be deposited. A small piece of platinum wire gauze encircles the tube extending from the edge of the flame to within 1½ mm. of the wet tissue paper, which is kept cool by a flow of cold water over it.

It is also of advantage to use 3 rather than 5 amperes, from the fact that this current can more readily be obtained, and with less loss, from the ordinary electric light wires of a town supply. In Manchester, where the voltage is about 100, the 3 amperes can be obtained simply and conveniently by fixing two wires, A and B, shown in the accompanying *Fig.* 1, along a strip of wood,

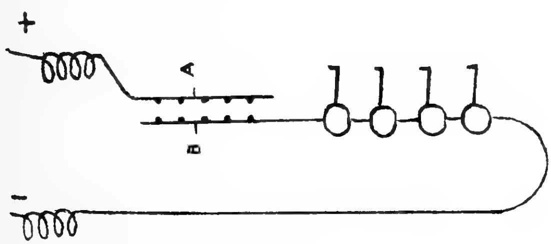


FIG. 1.

attaching a series of holders for filament electric lamps between them; any number of lamps can then be put in parallel till the desired amperage is obtained, the lamps themselves thus acting the part of the special plugs used by the Committee for adjusting the electric light supply for their apparatus. I find that one 50 and two 32 candle lamps, when put in parallel between the wires A and B, raised the amperage to three, whilst it required four 50 candle power lamps so placed to give 5 amperes. The dots on the disjoined wires shew how the lamps are inserted, and the circles further on shew 4 sets of apparatus working in series at the same time, but about a dozen may be so worked if required from the same current.

The remarkable fact was observed by Dr. T. E. Thorpe that arsenic, when it existed in the form of pentoxide, was not liberated at all from the platinum kathode of the Committee's apparatus, and it became necessary in using it to reduce any of the arsenic which might exist in that form to the condition of the trioxide by boiling with ½ a gramme of potassium metabisulphite and 5 c.c. of dilute sulphuric acid before introducing it into the apparatus; this complicates the process a little and is also a source of loss of arsenic, because on condensing the steam produced during the boiling process the presence of a minute quantity of arsenic was detected in the distillate, the amount evaporated however does not seriously interfere with the result.

I have simplified the Committee's electrolytic apparatus by doing away with the bell glass and grinding a glass stopper into the top of a small porous jar, 3 inches in height by 1½ inches internal diameter, with about $\frac{1}{10}$th inch thickness of wall. The stopper is provided with two openings, through one of which projects the narrowed end of a circular zinc rod which constitutes the kathode, about $\frac{5}{32}$nds inch in diameter and 1¾ inch long, the thicker part being 2 inches long by about ½ inch diameter. The other opening in the stopper is used for the double purpose of providing an exit for the hydrogen and for introducing the liquid. *Plate* VII., *Fig.* 1, shows the apparatus, with a section removed in the drawing, to shew the position of the pure zinc kathode. I have dispensed with the glass stopper used in the Committee's apparatus for introducing the liquid to be tested, and employed the method previously devised by me for the Marsh-Berzelius apparatus, viz., a thin glass rod rounded at the bottom and ground into the end of the tube used for holding the suspected liquid. See diagram, opposite page 10, Volume 47, of the Society's *Memoirs and Proceedings*, and explanation therein given.

This device is important when the cooling method is being used; the liquid can thus be run into the porous jar of the apparatus without shaking or disturbing it, as any shaking would displace the narrow glass tube delivering the cold water on to the fine drawn out portion of the glass tube through which the hydrogen passes.

The negative wire is joined to the zinc, which projects through a paraffined cork, and the positive to the deep band of platinum foil outside the porous jar. The method for accurately determining the point at which the mirror should be deposited by the cooling method is described on page 6, Vol. 47, of the *Memoirs* of the Society. If the wires have been properly joined up the ozone smell emitted from the anode can be at once detected.

In order to use as little liquid as possible for conducting the electric current to the anode the porous jar, surrounded by the closely fitting platinum foil anode, is set in a glass beaker, about ⅛th of an inch internal diameter wider than the external diameter of the porous jar; only about 10 c.c. of sulphuric acid (1 of acid to 7 of water) being used to fill the annular space between the pot and the jar. This is important, as the Committee's method requires a comparatively large quantity of the valuable arsenic-free sulphuric acid for each test.

The resistance of this cell is found to be about 1 ohm as against 1½ ohms for the Committee's apparatus.

The following shews the amount of gas yielded and the sizes of the hydrogen flames produced by the different amperages:—

Amperage.	Quantity of Hydrogen liberated per minute.	Size of flame as measured by Calipers placed close to the flame.	
		Millimetres.	
		Height.	Width.
3	21 c.c.	4	3
4	28 ,,	4·5	4
5	35 ,,	5	5
6	42 ,,	5·5	5
7	49 ,,	6	5·5
8	56 ,,	7	5·5

Influence of Amyl Alcohol and of Sugar on the detection and estimation of Arsenic.

The Committee say that beer may be tested directly in their appaartus, and to prevent frothing they recommend the addition of amyl alcohol, which they say does not interfere with the result. To test this point, I made a number of experiments by using 50 c.c. of solutions containing different quantities of As_4O_6 per gallon.

The first series of experiments was made in the Committee's electrolytic apparatus with a current of 5 amperes, and without cooling the tube at the point at which the mirror was produced. The process followed being exactly the one recommended by them.

Four different quantities of As_4O_6 were tried, viz., $\frac{1}{25}$, $\frac{1}{50}$, $\frac{1}{100}$, and $\frac{1}{200}$th of a grain per gallon, and two experiments were made with each of these quantities without the addition of amyl alcohol, and two with 2 c.c. (as recommended by the Committee) of amyl alcohol in the apparatus, the tubes containing the resultant mirrors were mounted and photographed, and the results obtained are shown in *Plate* VIII., *Fig.* 2. The first tube is a "blank" test done with the reagents alone, and it shows no trace of mirror. The two tubes containing the arsenic mirrors which follow, marked "without," are those produced from 50 c.c. of a solution containing $\frac{1}{25}$th of a grain of As_4O_6, and the next two shew the same experiment repeated, but with the exception that 2 c.c. of amyl alcohol were put into the apparatus. The mirrors produced when amyl alcohol was used with this comparatively large quantity of arsenic trioxide shew less than those without amyl alcohol, but the difference becomes more marked as the quantity of arsenic present becomes smaller. The second set of four mirrors (same *Plate*) were made each from 50 c.c. of a solution containing $\frac{1}{50}$th of a grain per gallon. The first two tubes were obtained without amyl alcohol, and the second two with 2 c.c. of amyl alcohol. The mirrors are seen to be considerably smaller in the experiments with amyl alcohol than in those without it.

In the third set 50 c.c. of solution, containing $\frac{1}{100}$th of a grain per gallon (which is the maximum which the Committee recommends should be allowed in beer) were used. Those without amyl alcohol show pretty strong mirrors, whilst those with amyl alcohol show practically no mirrors, and it must be remembered that the quantity of beer recommended to be employed for this test by the Committee is 25 c.c., or only one-half of the quantity used in this experiment, so that it does not appear satisfactory under any circumstances to permit the use of amyl alcohol.

In the fourth set of experiments 50 c.c. of a solution containing $\frac{1}{200}$th of a grain of As_4O_6 per gallon were employed (this being the actual amount of As_4O_6 which would be present in the apparatus from a beer which is recommended as the limit of As_4O_6 permissible in beer), without amyl alcohol faint mirrors are shown, with amyl alcohol no mirrors at all are produced.

Beer contains sugar and other organic compounds which might also influence the results, and the next series of experiments were made to find what influence different kinds and quantities of sugar would have on the resulting mirrors. The first of this series was made strictly in accordance with the instructions of the Committee, but using 50 c.c. of a solution containing $\frac{1}{100}$th of a grain per gallon, instead of 25 c.c. The first tube *Plate* IX., *Fig.* 1, was a blank (made with the reagents alone), and shows no mirrors; for this reason the tube is scarcely visible in the print. The mirror in the second tube was produced from the solution without either amyl alcohol or sugar, and shews a well-marked deposit. The mirror in the third tube was produced whilst using 2 c.c. of amyl alcohol alone, and shows a trace of a mirror. The fourth and fifth tubes were obtained when using 2 c.c. of amyl alcohol, but the former contained also 5 grammes, and the latter 10 grammes of invert sugar. In neither of these was any trace of an arsenic mirror produced, and yet there is present double "the permissible quantity" of arsenic in the apparatus, according to the Committee's instructions to use 25 c.c. of the beer.

The fifth and sixth tubes show the effects of the invert sugar alone, and indicate that invert sugar in moderate quantity does not so seriously interfere with the test as amyl alcohol; 5 grammes, however, prevent the formation of the full-sized mirror, and 10 grammes seriously interfere with its production.

The fifth series, *Plate* IX., *Fig.* 2, was made to ascertain what influence different quantities of glucose each with 2 c.c. amyl alcohol would have on the production of the mirrors when using 50 c.c. of a solution containing $\frac{1}{100}$th of a grain of As_4O_6 per gallon, and cooling the tubes at the point at which the mirrors were formed.

The first tube (scarcely visible) is the blank with the reagents alone showing no trace of mirror, the second is without either amyl alcohol or glucose, and shows a short dense mirror. The third tube is with 2 c.c. of amyl alcohol alone, and shows a less dense mirror than the one without alcohol, but the difference here is not nearly so marked as it is in the duplicate experiments shown in the previous plate, which proves the advantage of the cooling over the non-cooling method. The following five tubes show the influence of the combined effects of 2 c.c. of amyl alcohol with 1, 2, 5, 10, and 20 grammes of glucose respectively, and indicate that glucose has a marked influence in preventing the formation of the arsenic mirrors.

The sixth series, *Plate* X., *Fig.* 1, is a repetition of the fifth series, but using double the quantity of arsenic, viz., $\frac{1}{50}$th of a grain per gallon, and without cooling the tubes at the point at which the mirrors were produced.*

The seventh series, *Plate* X., *Fig.* 2, shows the arsenic obtained from eight samples of beer, marked A to H. Those on the right are obtained by the Marsh-Berzelius process when using 25 c.c. of each sample, after completely destroying the organic matter with sulphuric and nitric acids, and removing the latter as already described by me. Each shows different sized mirrors by the Marsh-Berzelius process, A containing $\frac{1}{150}$th B $\frac{1}{125}$th, C $\frac{1}{100}$th, D $\frac{1}{200}$th, E $\frac{1}{125}$th, F $\frac{1}{125}$th, G $\frac{1}{125}$th, and H $\frac{1}{100}$th of a grain of As_4O_6 per gallon ; whilst with the Committee's electrolytic process, using the beer direct, no trace of mirror is obtained from any of them, and the tubes are therefore all but invisible, their positions being indicated by the alphabetical letters.

* The mirror in the experiment in which 5 grammes of sugar were employed shows lighter in the print than it does in the photograph or in the tube itself.

From these results I conclude that in using 25 c.c. of beer, as recommended by the Committee, and completely destroying the organic matter, a very faint mirror is produced with those containing $\frac{1}{100}$th of a grain per gallon, but when the beer is used direct with amyl alcohol no mirror at all is produced, and therefore this direct method fails to detect an amount considerably greater than that which the Committee regard as sufficient to condemn the sample.

I take this opportunity of thanking my assistant, Mr. Samuel Bateman, B.Sc. (Vict.), for the great care and intelligence which he has bestowed on the carrying out of these experiments with me.

W. Thomson's Electrolytic Apparatus.

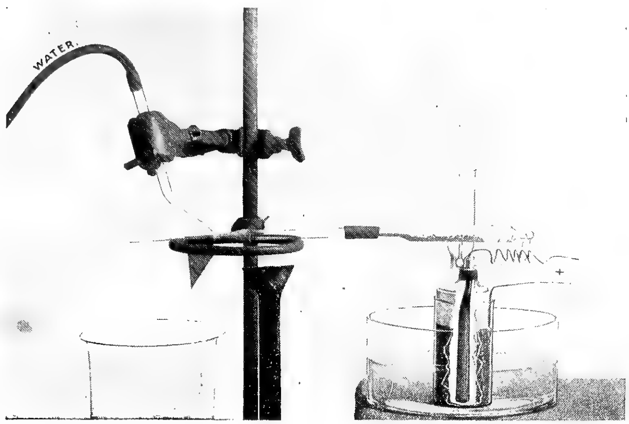


Fig. 1.

Fig. 2 shews the rate at which the Arsenic is removed from a solution, containing $\frac{1}{50}$th of a grain of As_4O_6 per gallon—50 c.c. being used, in the apparatus shewn in *Plate* I. (A) with 5 amperes, (B) with 3 amperes of current. The mirrors shewn were obtained during periods of 5 minutes till all the Arsenic was removed.

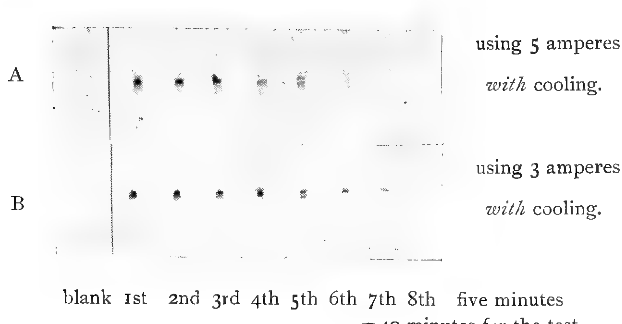
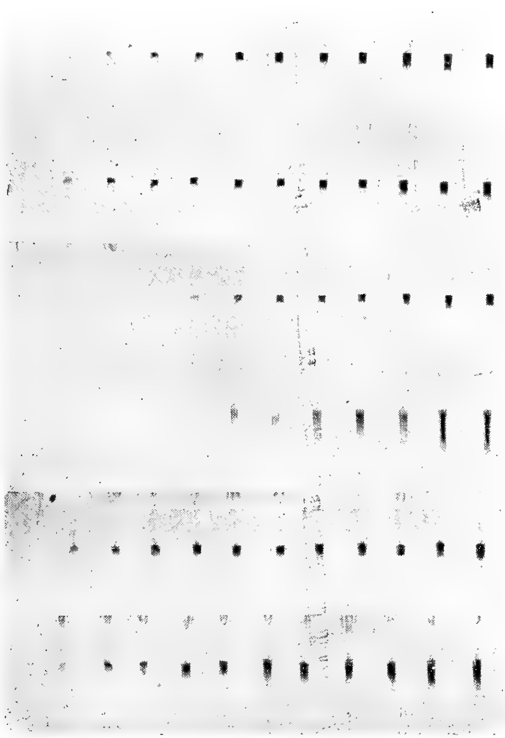


Fig. 2.

Fig. 1 shews the Arsenic mirrors obtained when using 50 c.c. of solutions containing the amounts of As_4O_6 in the fractions of a grain per gallon given below, by the Committee's Electrolytic Method as compared with the results obtained by other methods.



A — Electrolytic Method with granulated Zinc in contact with platinum wire as Kathode (3 amperes), *with* cooling.

B — Marsh-Berzelius Method, *with* cooling.

C — Committee's Electrolytic Method—*with* cooling (3 amperes).

D — Ditto *without* cooling (5 amperes).

E — My own Electrolytic Method with Zinc rod as Kathode (3 amperes *with* cooling).

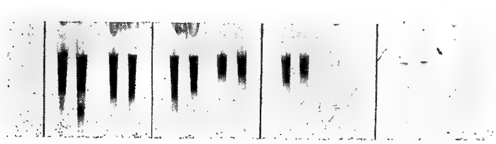
F — Ditto *with* cooling (5 amperes).

blank $\frac{1}{1000}$ $\frac{1}{500}$ $\frac{1}{400}$ $\frac{1}{300}$ $\frac{1}{250}$ $\frac{1}{200}$ $\frac{1}{150}$ $\frac{1}{125}$ $\frac{1}{100}$ $\frac{1}{80}$ $\frac{1}{60}$ grain per gallon (when using 50 c.c.)

Fig. 1.

Fig. 2 shews the influence of amyl alcohol on the formation of Arsenic mirrors when using the Committee's Electrolytic process, with 50 c.c. of solutions containing the quantities of As_4O_6 per gallon given below. "without" means, without amyl alcohol.

with-out with with-out with with-out with with-out with 2 c-c. amyl alcohl.



5amperes *without* cooling.

blank $\frac{1}{25}$ $\frac{1}{50}$ $\frac{1}{100}$ $\frac{1}{200}$ grain As_4O_6 per gallon when using 50 c.c. of the solution.

Fig. 2.

The Committee's Electrolytic Method.

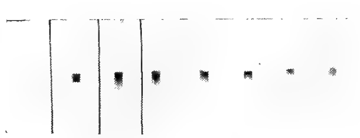
Fig. 1 shews the influence of 2 c.c. of amyl alcohol and of invert sugar on the production of arsenic mirrors, when using 50 c.c. of a solution containing $\frac{1}{100}$th grain per gallon. "With" means with amyl alcohol, and "without" means without amyl alcohol. The figures underneath give in grammes the quantities of invert sugar added to the apparatus. The ordinary method being employed.

5 amperes *without* cooling.

blank with-out amyl alcohol with | with 5—10 | without amyl alcohol and 5—10 grammes invert sugar.

Fig. 1.

Fig. 2 shews the influence of 2 c.c. of amyl alcohol and of alcohol and glucose together on the production of arsenic mirrors, when using 50 c.c. of a solution containing $\frac{1}{100}$th grain per gallon. "With" underneath means with amyl alcohol, "without" means without amyl alcohol. The figures underneath give in grammes the quantities of glucose added to the apparatus. The tubes were cooled at the points where the mirrors were produced.

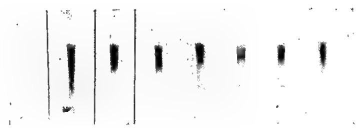


3 amperes *with* cooling.

blank with-out amyl alcohol with | with amyl alcohol and 1 2 5 10 20 grammes glucose.

Fig. 2.

Same as *Plate* IX., *Fig.* 2, but using solutions containing $\frac{1}{50}$th instead of $\frac{1}{100}$th of a grain per gallon without cooling.



5 amperes *without* cooling.

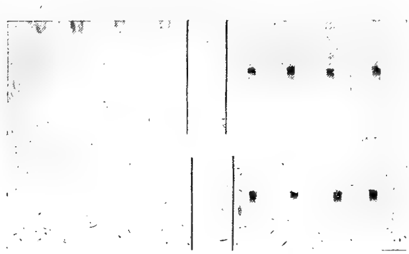
blank with- with with amyl alcohol and
out
amyl alco- 1 2 5 10 20 grammes glucose.
hol

Fig. 1.

Fig. 2 shews arsenic mirrors, from 8 samples of beer A B C D E F G H, using 25 c.c. of beer for each test, and cooling at the point at which the mirror should form.

A B C D blank | A B C D

5 amperes *with* cooling



E F G H | blank E F G H

Committee's Electrolytic Method working on the beer direct.

Marsh-Berzelius Method after completely destroying organic matter.

Fig. 2.

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XVIII. On the Discovery of *Elephas antiquus* at Blackpool.

By Prof. W. BOYD DAWKINS, M.A., D.Sc., F.R.S.

Received and Read April 26th, 1904.

The fossil mammalia are so rarely found in the boulder-clays of Great Britain that the discovery of a tooth of one of the rarer species of extinct elephants at Blackpool, is worthy of record. The tooth was forwarded to me by Mr. W. E. Robinson, of Poulton-le-Fylde, along with the following letter. It was found in 1898 "on the north shore at Blackpool, 100 yards or more from the base of the cliff, and embedded about three-fourths of its depth in the solid clay, which in some places is, or rather was then, denuded of the sand. We (my wife and son were with me) had some difficulty in digging it out with our umbrellas."

The tooth on comparison with the specimen in the British Museum presents the characteristic narrow shape and coarse plicated enamel, and wide plates of *Elephas antiquus.* It consists of the six posterior unworn plates with a portion of the seventh, together with the talon, of the last left true molar (M. 3). It is a waterworn fragment which had been torn out of the jaw and broken before it was embedded in the clay. This latter point is proved by the presence of the sandy clay in the pulp cavities of the plates. It had probably originally rested in a fluvatile deposit on the land, and afterwards been transported to its resting place in the sandy boulder-clay on the foreshore at Blackpool.

The sandy boulder-clay forms the bottom of the

Blackpool cliffs, which rise to the north to a height of over 100 feet above the sea, and are mainly formed of glacial sands and gravels capped by an upper brown clay. These cliffs are rapidly being attacked by the sea, and have undoubtedly covered the spot where the *Elephas antiquus* was found. The clay in question, therefore, belongs to the Lower Boulder-clay series of the Lancashire and Cheshire plains, as defined by the Geological Survey of Great Britain.*

The question next to be considered is how did the tooth under discussion come to be embedded in the Lower Boulder-clay? It cannot be answered without examining the origin of the materials found in the boulder-clay. All the boulders, pebbles, and sand and fine clays of which it is chiefly composed have been picked up by glaciers in their course from the hills to the sea. In this case the transported blocks of stone from the hills of the Lake district and of the Highlands of Scotland point out the position of the ice sheds. It is, however, very improbable that these materials were deposited by the melting of the glaciers on the land, because the coarser and finer elements have been dropped together without the sorting action of the glacier streams, which invariably carry the clayey element far away from the sands and gravels which are left behind to form the moraine. There is no instance on record of horizontal sheets of boulder-clay, like that of the Lancashire and Cheshire plain, being formed in any part of the world by ice melting above the level of the sea. There is, on the other hand, clear proof that the boulder-clay was deposited in the sea. The marine shells which occur in it, up to 1,200 feet above the sea, and more particularly the foraminifera which range in it

***Memoirs of Geological Survey*, C. E. De Rance ; *Geology of the Country round Blackpool, Poulton, and Fleetwood.*

up to not less than 600 feet above the sea in Scotland, Wales, and Ireland, prove that the land was submerged to at least that extent during the deposit of the boulder-clays.*

We may therefore infer that the tooth in question was derived from the area of land which furnished the supply of boulders, gravel, sand and clay, or in other words the Lake District or Scotland.

The remains of the *Elephas antiquus* are found over a large area in Britain. They occur in the preglacial deposits of Pleistocene age in the Forest Bed of Norfolk and Suffolk along with those of the Mammoth, Irish Elk, Bison, Horse, Cave Bear and other fossil species, as well as in the preglacial Hyæna-den of Kirkdale in Northern Yorkshire and in the preglacial caves of both North and South Wales. They occur too in the preglacial deposit of Selsea on the Sussex shore. They have been found also in the Mid-Pleistocene deposits of the Thames Valley at Grays Thurrock in Essex, and at Crayford in Kent in association with the remains of most of the above fossil mammals.

The *Elephas antiquus* lived also in Southern and Eastern Britain in the later or post glacial division of the Pleistocene age, as, for example, in the river gravels of Bedford, and of Bath.

On the Continent the animal ranged in the Pleistocene age over France and Italy, and is found alike in the river deposits and in the caverns. In the Pleiocene age it lived in the Valley of the Rhone, and in that of the Arno. The

* The glacialists represented by Messrs. Lamplugh and Kendal account for these marine fossils in the boulder-clay, by the hypothesis that the ice picked them up from the bottom of the sea and carried them uphill to altitudes of more than 1,000 feet above the sea. That the ice took an opposite direction to this, is proved conclusively, not only by the distribution of the boulders from the higher grounds down to the sea, but also by the glaciation of the land which invariably points from the ice sheds to the sea.

species, therefore, is to be viewed as a Pleiocene elephant which survived into the Pleistocene age.

Its occurrence in the boulder-clay at Blackpool can only be explained by the fact that it was picked up and carried down to the sea by a glacier and floated by an iceberg that melted in the sea over the spot where it was found, during the period of glacial submergence as defined by Sir Charles Lyell.* It is a relic of the general destruction of the land surface in the glaciated area of Britain.

The only other cases of the discovery of fossil mammalia in the glacial deposits of Britain, known to me, are the following: two teeth of Mammoth found in the boulder-clay of Norfolk by Mr. John Gunn, and now in the Museum at Norwich, and a fragment of the tusk of the same species found in the glacial deposits of the Kirk-Michael shore in the Isle of Man.

To these may be added a molar of Mammoth in Sir Phillip Egerton's collection from the glacial sand of Sandbach, a second figured by Mr. Morton (*Trans. Liverpool Biol. Soc.*, xii., 1898, p. 155, Pl. x.), from Marbury, in the same deposit, and other teeth of the same species† in a peaty deposit under the boulder drift at Northwich.

The chief interest of the discovery at Blackpool consists in the fact that it is a striking illustration of the destruction of the preglacial surface deposits on the land in the glaciated area north of an east and west line joining London and Bristol. In that area there are but few cases of any of the preglacial river deposits having escaped destruction. The Forest Bed of Norfolk and Suffolk, a deposit at Bulbecks in Yorkshire, and some three or four cases in Scotland‡ are on record.

* Antiquity of Man.

† One of the molars is in the Manchester Museum, Owens College.

‡ These are considered by Dr. James Lutin to be 'interglacial.' I cannot however see any proof that this is the case.

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XIX. Tables of the Bessel Functions for pure imaginary values of the argument.

By J. G. ISHERWOOD, B.Sc.

(*Communicated by Dr. C. H. Lees*).

Received and read April 26th, 1904.

The complete integral of the equation

$$\frac{d^2y}{dx^2}+\frac{1}{x}\frac{dy}{dx}-\left(1+\frac{n^2}{x^2}\right)y=0.$$

may be written :—

$$y=AI_n(x)+BK_n(x)$$

where n is an integer, A, B are constants, and $I_n(x)$ and $K_n(x)$ are the functions to which the Bessel Functions reduce when the argument becomes imaginary. I_n and K_n obey the sequence law

$$\frac{2nK_n}{x}=K_{n-1}-K_{n+1}$$

K_0 and K_1 have already been calculated by W. S. Aldis, M.A. (v. *Proc. Roy. Soc.*, Vol. LXIV. p. 219), and it was suggested to me by Dr. C. H. Lees that the values of K_2, K_3, &c., correct to 5 figures would be useful for Physical work. I give below the results for values of x as far as 5·0, and of n as far as 10 inclusive, obtained by successive calculation by means of the sequence law.

The corresponding values of I_0, I, I_2, &c., are for convenience also reproduced from the tables at the end of Gray and Matthews' Treatise on Bessel Functions.

The values obtained for K_n have been checked by means of the relation

$$I_{n+1}\cdot K_n-I_nK_{n+1}=\frac{1}{x}\cos n\pi.$$

(*vide* Gray and Matthews, p. 68.)

If the values in the last two columns satisfy this relation, it is obvious that every previous pair must do so.

May 25th, 1904.

x	$I_0(x)$.	$I_1(x)$.	$I_2(x)$.	$I_3(x)$.	$I_4(x)$.	$I_5(x)$.	$I_6(x)$.	$I_7(x)$.	$I_8(x)$.	$I_9(x)$.	$I_{10}(x)$.
0	1·0000	0	0	0	0	0	0	0	0	0	0
·2	1·0100	·10050	·0^{2}50167	·0^{3}16708	·0^{5}41750	·0^{7}83472	·0^{8}13909	·0^{10}19866	·0^{10}24829	·0^{14}27585	·0^{16}27582
·4	1·0404	·20403	·02027	·0^{2}13467	·0^{4}67202	·0^{5}26845	·0^{7}89398	·0^{8}25524	·0^{10}63775	·0^{11}14166	·0^{13}28321
·6	1·0920	·31370	·046365	·0^{2}46022	·0^{3}34362	·0^{4}20556	·0^{5}10256	·0^{7}43883	·0^{8}16436	·0^{10}54731	·0^{11}16406
·8	1·1665	·43286	·084353	·011100	·0^{2}11013	·0^{4}87635	·0^{5}58202	·0^{6}33164	·0^{7}16545	·0^{9}73404	·0^{10}29319
1·0	1·2661	·56516	·13575	·022168	·0^{2}27371	·0^{3}27146	·0^{4}22489	·0^{5}15992	·0^{7}99606	·0^{8}55184	·0^{9}27529
1·2	1·3937	·71468	·20259	·039359	·0^{2}58007	·0^{3}68789	·0^{4}68209	·0^{5}58093	·0^{6}43354	·0^{7}28788	·0^{8}17216
1·4	1·5534	·88609	·28755	·064522	·011026	·0^{2}15190	·0^{3}17520	·0^{4}17369	·0^{5}15095	·0^{6}11678	·0^{8}81382
1·6	1·7500	1·0848	·39397	·099892	·019371	·0^{2}30356	·0^{3}39874	·0^{4}45060	·0^{5}44666	·0^{6}39424	·0^{7}31358
1·8	1·9896	1·3172	·52604	·14819	·032077	·0^{2}56248	·0^{3}82798	·0^{3}10495	·0^{4}11677	·0^{5}11573	·0^{6}10341
2·0	2·2796	1·5906	·68895	·21274	·050729	·0^{2}98257	·0^{2}16002	·0^{3}22464	·0^{4}27699	·0^{5}30442	·0^{6}30170
2·2	2·6291	1·9141	·88906	·29763	·077345	·016374	·0^{2}29195	·0^{3}44923	·0^{4}60761	·0^{5}73288	·0^{6}79748
2·4	3·0493	2·2981	1·1341	·40787	·11448	·026256	·0^{2}50814	·0^{3}84966	·0^{3}12499	·0^{4}16406	·0^{5}19435
2·6	3·5533	2·7554	1·4337	·54963	·16537	·040786	·0^{2}85045	·0^{2}15342	·0^{3}24368	·0^{4}34560	·0^{5}44256
2·8	4·1573	3·3010	1·7994	·73048	·23408	·061686	·013772	·0^{2}26636	·0^{3}45402	·0^{4}69146	·0^{5}95134
3·0	4·8808	3·9534	2·2452	·95975	·32571	·091206	·021684	·0^{2}44721	·0^{3}81370	·0^{3}13237	·0^{4}19464
3·2	5·7472	4·7342	2·7883	1·2489	·44665	·13226	·033325	·0^{2}72948	·0^{2}14102	·0^{3}24391	·0^{4}38155
3·4	6·7848	5·6701	3·4495	1·6119	·60490	·18861	·050153	·011604	·0^{2}23734	·0^{3}43470	·0^{4}72046
3·6	8·0277	6·7927	4·2540	2·0661	·81046	·26508	·074109	·018055	·0^{2}38932	·0^{3}75231	·0^{3}13163
3·8	9·5169	8·1404	5·2325	2·6326	1·0758	·36784	·10776	·027554	·0^{2}62427	·0^{2}12686	·0^{3}23357
4·0	11·302	9·7595	6·4222	3·3373	1·4163	·50472	·15446	·041330	·0^{2}98099	·0^{2}20902	·0^{3}40379
4·2	13·442	11·706	7·8684	4·2120	1·8513	·68571	·21863	·061048	·015139	·0^{2}33734	·0^{3}68194
4·4	16·010	14·046	9·6258	5·2955	2·4046	·92342	·30597	·088939	·022989	·0^{2}53438	·0^{2}11277
4·6	19·093	16·863	11·761	6·6355	3·1060	1·2338	·42389	·12798	·034400	·0^{2}83235	·0^{2}18297
4·8	22·794	20·253	14·355	8·2903	3·9921	1·6369	·58191	·18210	·050798	·012768	·0^{2}29178
5·0	27·240	24·336	17·506	10·331	5·1082	2·1580	·79229	·25649	·074117	·019316	·0^{2}45800

x	$K_0(x)$.	$-K(x)$.	$K_2(x)$.	$-K_3(x)$.	$K_4(x)$.	$-K_5(x)$.	$K_6(x)$.	$-K_7(x)$.	$K_8(x)$.	$-K_9(x)$.	$K_{10}(x)$.
0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
·2	1·7527	4·7760	49·512	995·02	29900·	11970×10^2	59880×10^3	35940×10^5	25164×10^7	20135×10^9	18124×10^{11}
·4	1·1145	2·1843	12·036	122·55	1850·2	37127·0	93003×10	27938×10^3	97876×10^4	39178×10^6	17640×10^8
·6	·77752	1·3028	5·1203	35·438	359·50	4828·8	80839·0	16216×10^2	37918×10^3	10128×10^5	30422×10^6
·8	·56534	·86178	2·7198	14·461	111·17	1126·2	14189·0	21396×10	37585×10^2	75383×10^3	16999×10^5
1·0	·42102	·60191	1·6248	7·10126	44·232	360·96	3653·8	44207·0	62255×10	10005×10^3	18071×10^4
1·2	·31851	·43459	1·0428	3·9106	20·596	141·22	1197·4	12115·0	14254×10	19126×10^2	28832×10^3
1·4	·24365	·32083	·70199	2·3265	10·673	63·314	462·92	4031·2	40775·0	47002×10	60839×10^2
1·6	·18795	·24063	·48874	1·4625	5·9731	31·328	201·77	1544·6	13717·0	13872×10	15743×10^2
1·8	·14593	·18262	·34884	·95783	3·5416	16·698	96·310	658·77	5220·0	47059·0	47581×10
2·0	·11389	·13986	·25376	·64738	2·1959	9·4310	49·351	305·54	2188·1	17810·0	16248×10
2·2	·089269	·10789	·18736	·44854	1·4106	5·5782	26·766	151·57	991·33	7361·2	61219·0
2·4	·070217	·083724	·13999	·31704	·93258	3·4256	15·206	79·456	478·70	3270·8	25009·0
2·6	·055398	·065284	·10562	·22777	·63124	2·1700	8·9775	43·605	243·77	1543·7	10931·0
2·8	·043819	·051112	·080328	·16587	·43575	1·4108	5·4742	24·872	129·83	766·78	5059·1
3·0	·034739	·040156	·061510	·12217	·30585	·93776	3·4317	14·664	71·866	397·95	2459·5
3·2	·027594	·031642	·047371	·090856	·21773	·63517	2·2026	8·8950	41·118	214·49	1247·6
3·4	·021958	·024998	·036663	·068131	·15689	·43729	1·4430	5·5302	24·214	119·48	656·75
3·6	·017499	·019794	·028496	·051456	·11425	·30536	·96246	3·5135	14·626	68·519	357·22
3·8	·013965	·015705	·022232	·039107	·083980	·21591	·65215	2·2753	9·0350	40·317	200·01
4·0	·011159	·012483	·017401	·029884	·062227	·15434	·44807	1·4985	5·6930	24·271	114·91
4·2	·0089274	·0099382	·013659	·022947	·046440	·11140	·31169	1·0019	3·6515	14·912	67·561
4·4	·0071491	·0079232	·010750	·017696	·034881	·081116	·21923	·67903	2·3798	9·3127	40·477
4·6	·0057304	·0063250	·0084800	·013699	·026348	·059521	·15574	·46580	1·5734	5·9385	24·811
4·8	·004597	·0050552	·0067030	·010641	·020004	·043981	·11163	·32306	1·0539	3·8360	15·439
5·0	·003691	·0040446	·0053090	·0082910	·015258	·032704	·080666	·22630	·71409	2·5114	9·7550

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XX. Note on the Eye of the Mole.

By F. A. BRUTON, M.A.

Received April 16th, read April 26th, 1904.

On November 18th, 1902, a paper entitled "A contribution to our knowledge of the Mole," by Mr. Lionel Adams, was communicated to the Society by Dr. Hoyle, in which reference was made to the statement by St. Hilaire that "the eye of the mole is more developed in the fœtus than in the adult." I happen to have been making some observations of Moles, and as two specimens which I have found in traps this year have turned out to be females with young, I thought members may like to see how well the eye is shewn in the fœtus. Mr. Adams stated that the earliest date at which he had found a fœtal litter was April 13th, and these he estimated were within three days of birth. The first mole I examined was trapped on April 1st, so that the young, five in number, and ¾ inch long, were probably within several weeks of birth. The second was taken on April 23rd. The young in this case were six in number, and about 1¼ inch in length. In both instances the eye of the fœtus may be easily and distinctly seen without the aid of a lens, and when the fœtus was taken from the uterus it appeared as a clear black circle, apparently unprotected, about half way between the ear and the tip of the snout. Other points well shewn in the fœtus are the ear, the tongue, the snout, and the front claw.

In the *Proceedings of the Zoological Society* (Part xix. 1851, p. 129) there is a detailed account of the dissection of the mole's eye, in which it is stated that "notwithstanding the small size of the eye of the mole, its appearance in fœtal development is early; thus in a fœtus recently examined the length of which was about ¾ inch the eyes were distinct; they were visible, conspicuous in the naked face, not much smaller than those of the adult, and but little different in appearance. The diameter of each was about $\frac{1}{160}$ inch."

The chief points noted in the dissection of the eye of the adult mole were, briefly:

1. There is no orbit: the eye lies immediately beneath the skin, with no bony protection whatever.
2. There are no eyelashes, and the presence of eyelids is doubtful.
3. One muscle only was found—an abductor.
4. The aperture in the skin was $\frac{1}{25}$ inch in diameter: eyeball $\frac{1}{25}$ inch in diameter: iris, dark brown: pupil, circular: lens, $\frac{1}{163}$ inch in diameter:
5. Traces of aqueous and vitreous humour were found.
6. As the eyes are very low down and far forward, the optic nerves are unusually long.

Darwin has this remark upon the subject (*Orig. Spec.* 6th ed., p. 110):—"The eyes of moles and of some burrowing rodents are rudimentary in size, and in some cases are quite covered by skin and fur. This state of the eyes is probably due to gradual reduction from disuse, but aided perhaps by natural selection . . . . As frequent inflammation of the eyes must be injurious to any animal, and as eyes are certainly not necessary to animals having subterranean habits, a reduction in their size, with the adhesion of the eyelids and growth of fur over them, might in such case be an advantage, and if so, natural selection would aid the effects of disuse."

Mr. Adams refers to the report that when a mole is thrown into water, the fur radiates from the eye, and so makes vision possible. He states that he has only seen this once, and then in the case of an expiring mole. Bartholomew, writing in the thirteenth century, seems to refer to the same phenomenon when he says: "et putaverunt aliqui quod illud corium rumpitur pre angustia quando incipit mori, et tunc incipit aperire oculos in moriendo que eos clausos habuit in vivendo."* [" And some men trow that the skin of the mole breaketh for anguish and sorrow when he beginneth to die, and beginneth then to open the eyes in dying that were closed living."] I have been told by a molecatcher that the eyes are so exposed when a mole is taken from the trap, but I have not verified this. I have myself seen the radiation of the fur most distinctly in the case of a living mole. At this season of the year moles work very near the surface of the ground in fields where the young crops are coming up, and may easily be caught by hand. In the case of a male which I caught in this way on April 24 of this year, I looked carefully for the eyes as I held the mole in my hand. At first they were not to be seen, but presently a distinct conical cavity was formed by radiation of the fur, at the bottom of which the black circular eye was clearly seen with no protection whatever. The partial exposure of the skin due to the radiation of the fur gave the impression that the fur immediately surrounding the eye was of a lighter shade than the rest.

Aristotle makes frequent mention of the mole in his works *De partibus animalium* and *De historia animalium*, almost invariably referring to the fact that the mole cannot see, though it possesses eyes. In at least two

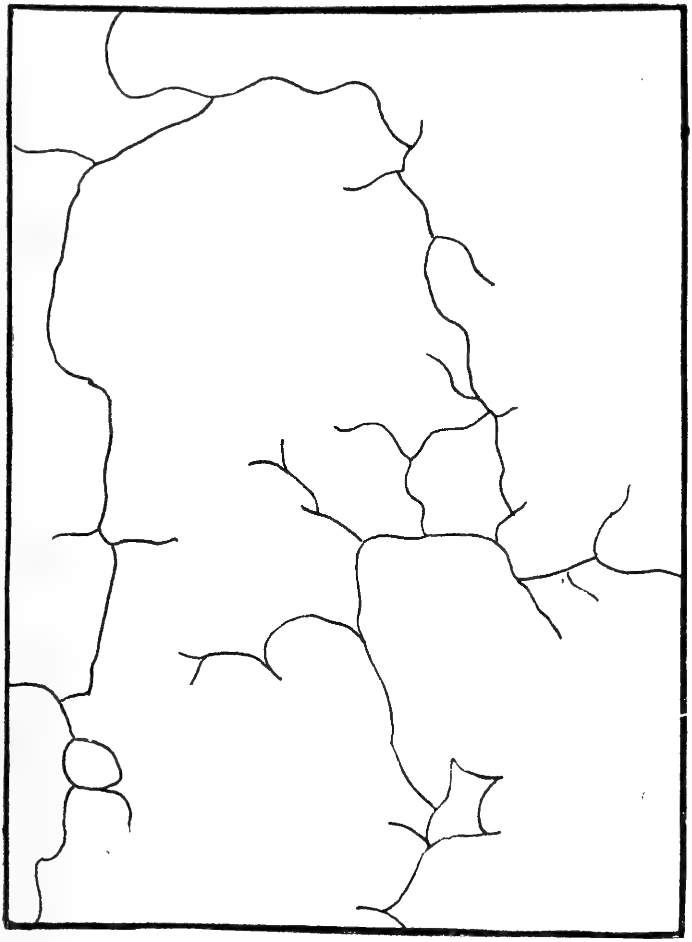
**Bartholomæus Anglicus* "De Proprietatibus Rerum," Lib. 18, cap. 100, fol. Cologne, 1471; the English version is that of Trevisa, London, 1535.

places he suggests that the eyes have the appearance of having been injured at birth. The following passage is specially interesting, as containing also a reference to the existence of the pupil, the iris, the white of the eye, and the optic nerves:

τοῦτο γὰρ ὄψιν οὐκ ἔχει· ὀφθαλμοὺς γὰρ ἐν μὲν τῷ φανερῷ οὐκ ἔχει, ἀφαιρεθέντος δὲ τοῦ δέρματος ὄντος παχέος ἀπὸ τῆς κεφαλῆς κατὰ τὴν χώραν τὴν ἔξω τῶν ὀμμάτων ἔσωθέν εἰσιν οἱ ὀφθαλμοὶ διεφθαρμένοι, πάντ' ἔχοντες ταὐτὰ τὰ μέρη τοῖς ἀληθινοῖς· ἔχουσι γὰρ τό τε μέλαν καὶ τὸ ἐντὸς τοῦ μέλανος τὴν καλουμένην κόρην καὶ τὸ κυκλώπιον, ἐλάττω μέντοι ταῦτα πάντα τῶν ὀφθαλμῶν τῶν φανερῶν. Εἰς δὲ τὸ ἔξωθεν οὐδὲν σημαίνει τούτων διὰ τὸ τοῦ δέρματος πάχος, ὡς ἐν τῇ γενέσει πηρουμένης τῆς φύσεως· εἰσὶ γὰρ ἀπὸ τοῦ ἐγκεφάλου, ᾗ συνάπτει τῷ μυελῷ, δύο πόροι νευρώδεις καὶ ἰσχυροὶ παρ' αὐτὰς τείνοντες τὰς ἕδρας τῶν ὀφθαλμῶν τελευτῶντες δ' εἰς τοὺς ἄνω χαυλιόδοντας.

De hist. animal. Lib. IV. cap. viii.

[*Translation.*—"The mole has not sight: it has no eyes visible; but when the skin, which is thick, is taken off the head, in the place where eyes [*i.e.* usually] appear on the surface, there underneath are its eyes atrophied [*διεφθαρμένοι*], with all their parts corresponding to those of genuine eyes—the black [*τὸ μέλαν*, ? the iris], and that which is within the black, called the pupil, and the white of the eye [*κυκλώπιον*, reading doubtful], but all smaller than in eyes on the surface. None of these shows on the surface, owing to the thickness of the skin, as though their natural powers were stunted at the birth. From the brain, where it joins the spinal cord [*τῷ μυελῷ*] two strong nerve channels run close past the sockets of the eyes, ending in the upper eyeteeth."]



Tracing of one of the mole runs that are seen at this season, when the animals work near the surface among the young crops. As the mole extends the run a low ridge is formed on the surface of the field. The runs appear to radiate generally from a bank, in which it may be presumed that the fortress is situated.

XXI. A Diagnostic Key to the Genera of Recent Dibranchiate Cephalopoda.

BY WILLIAM E. HOYLE, D.SC.

Received and Read February 2nd, 1904.

The subjoined key has been drawn up in preparation for a systematic account of the recent Cephalopoda to be published in the "Tierreich," undertaken by the German Zoological Society and continued by the Berlin Academy of Sciences. Publicity is now given to it, in the hope that my colleagues, who attempt to identify specimens by its means, will communicate with me regarding any difficulties or equivocal results which they may encounter.

In its elaboration the attempt has been made to utilise external characters alone, and to resort to internal structure only when necessary. This is the main cause of the differences between the scheme here presented and those of Mr. Goodrich* and Dr. Pfeffer,† who have published keys for the discrimination of the Œgopsida. The memoir of the latter author, the result of years of work at this group and of an unrivalled acquaintance with immature forms, has been of the greatest assistance to me, and if I have not followed him in all his conclusions I have ventured to reject them only with diffidence. If I may say so, I think he is a little too disposed to lump species and to split genera. The result is seen in the fact that of his 50 genera 43 contain only one species each.

* "Note on a Large Squid," *Journ. Mar. Biol. Assoc.*, n.s., vol. 2. p. 318—321, 1892.

† "Synopsis der oegopsiden Cephalopoden," *Mitt. Naturhist. Mus.* (*2 Beiheft Jahrb. Hamburg. Wiss. Anst.*, vol. 17), vol. 17, p. 147—198, 1900. In addition to being indebted to Dr. Pfeffer's published writings I have to thank him for information given both in conversation and by letter.

Owing to the almost exclusive use of external characters the arrangement here given does not always follow grounds of morphological consequence; in several instances owing to some exceptional character forms occur out of their proper order. The discrimination by this key presupposes the examination of adult specimens in good condition; the identification of young or fragmentary examples can only be accomplished by careful comparisons.

In order to furnish the reader with a survey of the classification adopted I give at the outset a list of the families recognized and of the genera included in each. References to descriptions and figures will be found in my "Catalogue of Recent Cephalopoda" (*Proc. Roy. Phys. Soc. Edinburgh*, vol. 9, p. 205—267, 1886) and "Supplement, 1887—96" (*op. cit.*, vol. 12, p. 363—375, 1897); subsequent works so far as they relate to new genera, are given in the "Notes" (see p. 17).

OCTOPODA.

CIRROTEUTHIDÆ :—*Cirroteuthis*, *Stauroteuthis*, *Froekenia*, *Opisthoteuthis*.

AMPHITRETIDÆ :—*Amphitretus*.

ALLOPOSIDÆ :—*Alloposus*, *Bolitaena*.

ARGONAUTIDÆ :—*Argonauta*, *Ocythoë*, *Tremoctopus*.

POLYPODIDÆ : — *Polypus*, *Tritaxeopus*, *Pinnoctopus*, *Cistopus*, *Scaeurgus*, *Moschites*, *Hoylea*, *Eledonella*, *Japetella*.

DECAPODA.

MYOPSIDA.

IDIOSEPIIDÆ :—*Idiosepius*.

SEPIOLIDÆ : — *Sepiola*, *Inioteuthis*, *Euprymna*, *Stoloteuthis*, *Heteroteuthis*, *Nectoteuthis*, *Sepioloidea*, *Sepiadarium*, *Rossia*, *Semirossia*, *Promachoteuthis*.

LOLIGINIDÆ :—*Loligo, Sepioteuthis, Loliolus, Lolliguncula.*

SEPIIDÆ :—*Sepia, Sepiella, Hemisepius.*

ŒGOPSIDA.

SPIRULIDÆ :—*Spirula.*

GONATIDÆ :—*Gonatus.*

ONYCHOTEUTHIDÆ :—*Onychoteuthis, Ancistroteuthis, Chaunoteuthis, Teleoteuthis, Tetronychoteuthis, Lycoteuthis.*

ENOPLOTEUTHIDÆ :—*Enoploteuthis, Abralia, Thelidioteuthis, Ancistrochirus, Pterygioteuthis, Pyroteuthis, Abraliopsis, Octopodoteuthis, Cucioteuthus.*

THAUMATOLAMPADIDÆ :—*Thaumatolampas.*

ARCHITEUTHIDÆ :—*Architeuthus.*

TRACHELOTEUTHIDÆ :—*Tracheloteuthis, Brachioteuthis.*

BATHYTEUTHIDÆ :—*Bathyteuthis, Ctenopteryx.*

HISTIOTEUTHIDÆ :—*Histioteuthis, Calliteuthis, Meleagroteuthis.*

THYSANOTEUTHIDÆ :—*Thysanoteuthis.*

OMMASTREPHIDÆ :—*Ommastrephes, Symplectoteuthis, Sthenoteuthis, Dosidicus, Illex, Todaropsis, Hyaloteuthis, Rhynchoteuthis.*

CHIROTEUTHIDÆ :—*Chiroteuthis, Doratopsis, Mastigoteuthis.*

GRIMALDITEUTHIDÆ :—*Grimalditeuthis.*

GALITEUTHIDÆ :—*Galiteuthis.*

CRANCHIIDÆ :—*Cranchia, Pyrgopsis, Leachia, Taonius.*

INCERTAE SEDIS.[1]

Dubioteuthis, Lepidoteuthis, Cirrobrachium.

[1] The small numbers refer to the notes at the end of the Key.

KEY.

Suckers sessile, with no horny ring; normally with eight arms (OCTOPODA) .... 1[2]
Suckers stalked, with a horny ring; normally with eight arms and two tentacles (DECAPODA) .... 20[2]

1\. A pair of oar-shaped fins projecting from the sides of the body; suckers in a single row (CIRROTEUTHIDÆ) 2
No oar-shaped fins 5

2\. Body not depressed, length at least equal to breadth ... 3
Body much depressed, not distinctly separated from the arms; whole animal disc-shaped .... *Opisthoteuthis.*

3\. A well-developed web between the arms 4
No web between the arms .... *Froekenia.*[3]

4\. Internal cartilage saddle-shaped, placed transversely across the body .... *Cirroteuthis.*
Internal cartilage horse-shoe shaped; placed around the aboral extremity of the body .... *Stauroteuthis.*

5\. Mantle adherent to the funnel in the middle line ventrally, so that there are two openings into the mantle cavity, one on either side. (AMPHITRETIDÆ). *Amphitretus.*[4]
Mantle aperture single., ... 6

6\. An external shell. (ARGONAUTIDÆ) .... *Argonauta* ♀.
No external shell 7

7\. Body soft and gelatinous. (ALLOPOSIDÆ) 8
Body firm 9

8. Suckers in two rows .... *Alloposus.*
   Suckers in a single row.................................. *Bolitaena.*

9. Mantle connection consisting of either deep grooves and ridge, or cartilaginous knobs on the mantle and corresponding hollows at the base of the funnel; aquiferous pores present; hectocotylus involving the whole arm, which is separable. (ARGONAUTIDÆ)... 10
   Mantle connection consisting of shallow folds on hinder margin of funnel and shallow groove on the mantle; no aquiferous pores; hectocotylus confined to tip of arm, never free. (POLYPODIDÆ) 13

10. Funnel organ made up of three separate portions; mantle connection cartilaginous; an aquiferous pore at either side of the siphon, none in the head. 11
    Funnel organ composed of numerous longitudinal lamellæ; mantle connection composed of membranous folds, without cartilage; an aquiferous pore at either side of the siphon and two in the head; hectocotylised arm on the right side .... *Tremoctopus.*

11. Body 10 cm. or more in length; with tubercles connected by ridges on the ventral aspect......... *Ocythoë* ♀
    Body 30 mm. or less in length, with one ventro-lateral arm developed in an oval sac and specially modified into a separable hectocotylus 12

12. Hectocotylus on the left side .... *Argonauta* ♂
    Hectocotylus on the right side....................... *Ocythoë* ♂

13. Suckers on the arms in a single row....................... 14
    Suckers on the arms in two rows 17
    Suckers on the arms in three rows .... *Tritaxeopus.*[5]

14. A narrow fin extending round the body ....*Hoylea.*
No fin 15

15. Body firm; arms comparatively long, usually at least twice the length of the body......................*Moschites.*
Body gelatinous, semitransparent; arms shorter than the body, except the third pair in some cases 16

16. A median septum present in the mantle cavity...*Eledonella.*[6]
No median septum in the mantle cavity ....*Japetella.*[6]

17. A broad fin on either side of the body, rendering the outline heart-shaped............................*Pinnoctopus*
No lateral fins.. 18

18. An aquiferous pore leading into a pouch between each pair of arms ....*Cistopus*
No aquiferous pouches 19

19. The third arm of the right side hectocotylised......*Polypus.*[7]
The third arm of the left side hectocotylised......*Scaeurgus.*[7]

20. A spiral internal shell, protruding on the dorsal and ventral surfaces. (SPIRULIDÆ)....................*Spirula.*[8]
No spiral shell 21

21. Eye covered by a continuous membranous lid. (MYOPSIDA) 22
Eye with a perforated lid. (ŒGOPSIDA) 39

22. Body short rounded, with separate ovate lateral or subterminal fins 23
Body oval or elongate, with fins either marginal or terminal.. 34

23. Body rather elongated; medio-dorsal margin of mantle free, but with no cartilaginous connecting apparatus; anterior part of right oviduct present along with complete left oviduct; both ventral arms hectocotylised. (IDIOSEPIIDÆ) .... *Idiosepius.*

Body short, saccular; medio-dorsal margin of mantle either continuous with head or with cartilaginous connection; right oviduct absent; one ventral or both dorsal arms hectocotylised......... (SEPIOLIDÆ) 24[9]

24. Dorsal margin of mantle fused in middle line so that the integument is continuous with that of the head 25

Dorsal margin of mantle free from the head and with a cartilaginous articulation ....(ROSSIINÆ) 32

25. Left ventral arm hectocotylised; mantle fused with the head in the mid-dorsal line; shell absent. (SEPIADARIINÆ) 26

Dorsal arms hectocotylised 27

26. A cartilaginous articulation with the mantle present at the base of the funnel; mantle margin notched; body longitudinally striped; pores on the under surface ....*Sepioloidea.*

Mantle fused with the base of the funnel on either side, no cartilaginous articulation ....*Sepiadarium.*

27. Dorsal margin of the mantle fused with the head; no cartilaginous articulation in the nuchal region. (SEPIOLINÆ) 28

Dorsal margin with a continuous fold, but with a cartilaginous articulation only in the anterior region; the mantle and body fused further back. (HETEROTEUTHINÆ) 31

28. A narrow lanceolate shell present; the direct connection between the head and mantle narrow (not exceeding about 8 mm.); left dorsal arm hectocotylised .... *Sepiola.*

Shell entirely absent; dorsal connection wide, about 15 mm. 29

29. Suckers in two rows on the arms and in four rows on the tentacular club 30

Suckers in four rows on the arms and in sixteen or more rows on the tentacular club .... *Euprymna.*

30. Arms only connected at the base by a narrow umbrella; ventral margin of the mantle not produced forwards under the head; fins moderate; left dorsal arm hectocotylised .... *Inioteuthis.*

Interbrachial umbrella extending half way up the arms; ventral surface of mantle with a brown shield-shaped patch, margin produced forwards; fins very large; both dorsal arms hectocotylised. *Stoloteuthis.*

31. Fins near the hinder end of the body, large; ventral mantle margin moderately produced not covering the funnel; right dorsal arm hectocotylised and fused at its base with the second .... *Heteroteuthis.*

Fins very large, midway along the mantle; ventral mantle margin much produced covering the funnel; distal portion of the arms with diminutive suckers on elongated stalks .... *Nectoteuthis.*

32. Fins at the hinder end of the body; very large in proportion to the body .... *Promachoteuthis.*

Fins at the sides of the body; small in proportion to the body 33

33. Rows of suckers not increasing in number towards the tips of the arms; stoutly built forms; both dorsal arms hectocotylised .... *Rossia.*

Rows of suckers increasing in number towards the tips of the arms; slightly built forms; only the left dorsal arm hectocotylised .... *Semirossia.*

34. Fins marginal extending the whole length of the mantle; body oval 35

Fins terminal, together heart-shaped or triangular in form; body cylindrical, more or less pointed behind. (LOLIGINIDÆ) 37

35. A hard cuttle-bone internally. (SEPIIDÆ) 36

A horny pen internally............................ *Sepioteuthis.*[10]

36. No glandular pores on the mantle .... *Sepia.*

A glandular pore at the posterior extremity between the fins.. *Sepiella.*

Two rows of pores on the inferior surface of the mantle .... *Hemisepius.*

37. Siphon without bridles; suckers without the raised margin round the horny ring; hectocotylisation affecting all the suckers of the left ventral arm...*Loliolus.*

Siphon with bridles and suckers with raised margin; hectocotylisation affecting only the distal portion of the arm.. 38

38. Fins together forming a spear-head or triangle; spermatophores received in the buccal region on a round cushion just below the mouth .... *Loligo*

Fins thick and short, forming a transverse oval; spermatophores received within the mantle near the left gill .... *Lolliguncula.*

39. Some of the suckers modified into hooks 40
No hooks 56

40. Suckers or hooks in four rows on the arms. (GONATIDÆ) *Gonatus.*
Suckers or hooks in two rows 41

41. The sessile arms bear only suckers. (ONYCHOTEUTHIDÆ) 42
The sessile arms bear hooks, usually with suckers also at the tips.........................(ENOPLOTEUTHIDÆ) 47

42. Body soft and gelatinous; tentacles rudimentary with bulbous knobs ....*Chaunoteuthis.*
Body firm and fleshy, tentacles present 43

43. Tentacular club with hooks on the central part in two rows 44
Tentacular club with hooks or suckers in four rows..... 45

44. Pen with a very strong keel, visible through the integument of the back as a well-defined dark streak; lateral wings of the pen clearly developed..*Onychoteuthis.*[11]
Pen with a slight keel, not visible through the integument; lateral wings absent or rudimentary *Ancistroteuthis.*[1]

45. Central part of the club with two central rows of hooks and two lateral rows of suckers ....*Teleoteuthis.*
Club with four rows of hooks or suckers 46

46. Mantle with shagreen-like tubercles; arms with rudimentary swimming-web..... ....*Tetronychoteuthis.*[12]
Mantle smooth; arms with a swimming-web provided with transverse ribs; buccal membrane darkly coloured ....*..Lycoteuthis.*[12]

47. Animal of large size; mantle more than 50 cm. long; fin rhomboid attached for the whole length of the mantle .... *Cucioteuthus.*

Animal small not exceeding 8 to 10 cm. in length of mantle 48

48. Tentacles absent in the adult; in the young shorter than the arms and with but few suckers on the club; body stumpy and rounded behind; suckers extending to the tips of the arms ...... *Octopodoteuthis.*

Tentacle longer than the arms and with hooks on the club 49

49. The ventral arms with a series of three spheroidal knobs at their tips .... *Abraliopsis.*

Tips of ventral arms normal 50

50. Luminous organs on the inferior semi-circumference of the eye-ball, covered by the integument and also in the mantle cavity 51

Luminous organs on the ventral surface of the mantle 53

51. Luminous organs not coexisting on the tentacles, eyes and in the mantle cavity 52

Luminous organs on the tentacles, under the eyes and on the ventral surface of the body (THAUMATOLAMPADIDÆ) *Thaumatolampas.*[1]

52. Tentacular club armed with suckers only; fixing apparatus consisting of two suckers and two pads *Pterygioteuthis.*

Tentacular club with hooks and suckers; fixing apparatus with six or more suckers and pads...*Pyroteuthis.*[14]

53. Luminous organs, few in number (not exceeding 20), comparatively large and tubercle-like 54
Luminous organs numerous and small 55

54. Luminous organs, about 9 on each side the mantle, leaving the median portion free; also on the stem of the tentacle, body rounded behind ... *Thelidioteuthis.*[15]
Luminous organs in the median line of the mantle; fin reaching to the anterior margin of the mantle and nearly to the posterior .... *Ancistrochirus.*

55. Luminous organs in seven rows down the ventral surface of the mantle; arms with only hooks; tentacle-club with two rows of fairly numerous hooks .... *Enoploteuthis.*
Luminous organs numerous and scattered all over the ventral surface; and a few on the dorsal surface; arms with suckers at the tips; a single row of few hooks on the tentacular club and two rows of suckers .... *Abralia.*

56. Funnel articulating with the inner surface of the mantle by a cartilaginous joint on either side 57
Funnel fused with the inner surface of the mantle on either side 75

57. Animals of gigantic size, mantle 2 to 3 metres in length; tentacle with a fixing apparatus consisting of alternating pads and suckers extending along the stem; pen feather-shaped with a terminal cone; siphonal articulation unknown.
(ARCHITEUTHIDÆ) *Architeuthus.*
Animal of moderate size; mantle length not exceeding 0·7 metre; generally much less 58

58.
- Articulating facet at the base of the siphon an elongated pit, without a transverse groove; articulating facet on the inner surface of the mantle a linear ridge without any transverse ridge 59
- Articulating facet on the siphon sub-triangular; facet on the mantle with longitudinal and transverse ridge, ⊥-shaped, or ⊣-shaped 65
- Articulating facet on siphon ear-shaped with an elevated margin; on the mantle a rounded tubercle, or a ridge with posterior elevation (CHIROTEUTHIDÆ) 73

59.
- Numerous luminous organs on the ventral aspect of the body, siphon, head and arms. (HISTIOTEUTHIDÆ) 60
- No luminous organs .... 62[16]

60.
- Horny rings of arm-suckers without teeth ......*Calliteuthis*.
- Horny rings of arm-suckers toothed....................... 61

61.
- In the adult an extensive web connecting all the arms except the ventral (in the young the web may be absent or rudimentary); luminous organs in a single row on the dorsal and lateral arms; three and two rows on the ventral.............................*Histioteuthis*.
- Web rudimentary; luminous organs close-set and numerous; on dorsal and dorso-lateral arms three rows, on the ventro-lateral four and on the ventral eight; and a single row of cartilaginous tubercles on the outer side of the dorsal and lateral arms and along the dorsal middle line of the mantle ... *Meleagroteuthis*.[17]

62. Arms with more than two irregular rows of suckers; tentacles with more than four rows of minute suckers; pen narrow anteriorly, with an expanded portion occupying the posterior half. (BATHYTEUTHIDÆ) 63

Arms with two rows, tentacular club with numerous (8 or more) rows of suckers; fin, rhomboid or cordate, transversely elongated. (TRACHELOTEUTHIDÆ) 64

63. Body, subgelatinous in texture; colour deep red; fins small, subterminal .... *Bathyteuthis.*[18]

Fin extending along the greater part of the mantle; supported by a series of parallel muscular trabeculæ, producing a resemblance to the fin of a fish *Ctenopteryx.*[18]

64. Fin subcircular, of moderate size, length and breadth not exceeding half those of the mantle; tentacular club in the middle with four rows of medium-sized suckers, which diminish somewhat distally; proximally with many rows of quite small suckers, which are continued along the stem first in four and then in two rows; pen with hollow cone, whose walls coalesce for a short distance at the extreme tip; the cone forming from a half to a third of the whole length of the pen .... *Tracheloteuthis.*[19]

Fin transversely rhomboidal, large, its length more than half, its breadth more than five-sixths of the length of the mantle; tentacular club with many (about sixteen) rows of very small suckers, of which the middle ones are larger; a few suckers are scattered over the stem; pen with a terminal hollow cone, whose margins do not seem to fuse, constituting two-fifths of the length of the pen......... *Brachioteuthis.*[19]

65. Fins rhomboidal, extending the whole length of the mantle; siphonal cartilage with a longitudinal groove from which a shorter one branches out ventrally, thus ⊣. ....(THYSANOTEUTHIDÆ) *Thysanoteuthis.*

Fins usually sagittate, broader than long; siphona cartilage with longitudinal groove, crossed by a posterior shorter transverse groove; thus ⊥. OMMASTREPHIDÆ. 66

66. Animal small, pelagic; tentacles fused into a proboscis-like organ .... *Rhynchoteuthis.*[20]

Animal large, or moderately large, tentacles normal..... 67

67. Funnel groove smooth, without a furrowed area (foveola) in its anterior portion; tentacles with no fixing apparatus.. 68

Funnel groove with a foveola; tentacles with fixing apparatus 69

68. Eight rows of suckers at the end of the tentacular club; rings of large tentacular suckers smooth ....*Illex.*

Four rows of suckers at the end of the tentacular club; large tentacular suckers with more than 30 acute teeth ....*Todaropsis.*

69. Sucker bearing portion of the tentacle extending more than half its length: fixing apparatus consisting of only a few pads and suckers, only distinguished from those of the dorsal row by small size and insignificant teeth ....*Ommastrephes.*[21]

Tentacle club less than half the length of the organ; fixing apparatus a distinct carpal group of pads and small suckers... 70

70. Cartilaginous articulation of the funnel fused with that of the mantle .... *Symplectoteuthis.*[22]
Cartilaginous articulation free 71

71. Ventral surface of the mantle with regularly arranged tubercles and depressed pits .... *Hyaloteuthis.*
Ventral surface smooth 72

72. Tips of the arms, slender, elongated and with very numerous minute suckers; trabeculæ of the lateral membrane of the arm extending beyond the web itself, except in the third pair... .... *Dosidicus.*
Arm tips normal; membrane on the ventral side of second and third arms much developed; web scarcely overpassed by the trabeculæ ......*Sthenoteuthis.*

73. Tentacle round and tapering to the extremity; no club formed; surrounded at the tip with numerous small suckers .... *Mastigoteuthis.*
Tentacle with a club-like expansion........................ 74

74. Tentacle very long, many times the length of the mantle; tentacle club with a well developed sucker at the extremity; club without a web; no longitudinal ridge in the siphonal articulation... *Chiroteuthis.*[23]
Tentacle not exceeding the mantle in length; club provided with a web and a rudimentary sucker at the end; siphonal groove with a longitudinal ridge *Doratopsis.*[23]

75. Nuchal cartilages developed; pen prolonged beyond the first fin, and bearing an accessory fin (often lost); arms with pigmented extremities. (GRIMALDITEUTHIDÆ) *Grimalditeuthis.*
Mantle fused with head in nuchal region; no accessory fin; arms with extremities normal 76

76. Tentacles with hooks..........(GALITEUTHIDÆ) *Galiteuthis.*
Tentacles (if present) with suckers only; no hooks. (CRANCHIIDÆ) 77

77. Body short and rounded; fins very small, terminal. *Cranchia.*
Body fusiform 78

78. Phosphorescent organs in the eyes; a row of chitinous tubercles on either side of the ventral aspect of the mantle 79
No phosphorescent organs on the eyes; no chitinous tubercles on the mantle.............................*Taonius.*

79. Mantle membranous; tentacles present: eyes with a strongly elevated chitinous ridge, dorsal to which are the phosphorescent organs; fin subquadrangular or triangular.......................................*Pyrgopsis.*
Mantle gelatinous; tentacles absent; eyes with no ridge but a row of luminous organs on the antero-lateral aspect; fin circular or transversely elliptical. *Leachia.*

NOTES.

1. *Lepidoteuthis*, JOUBIN, Céphalopodes provenant des campagnes de la "*Princesse-Alice*," *Campagnes scient. Monaco*, fasc. 17, 1900 [1901], p. 70—78, pl. 6, 7, 10, fig. 3—6, pl. 15, fig. 1, 2.
Dubioteuthis, JOUBIN, *op. cit.*, p. 102—105, pl. 15, fig. 8—10.
Cirrobrachium, HOYLE, Reports on the dredging operations of the "Albatross," &c. *Bull. Mus. Comp. Zool.*, vol. 43, No. 1, 1904, p. 28.

2. The use of the suckers as the primary character for this separation is necessitated by the fact that several genera of Decapods are normally devoid of tentacles (*e.g.*, *Chaunoteuthis*, *Leachia*), and that they are not unfrequently missing owing to accident.

3. *See* HOYLE, "Albatross" Report, p. 7, pl. 2, fig. 2, pl. 3, fig. 5.

4. *See* IJIMA and IKEDA, Notes on a specimen of Amphitretus pelagicus from the Sagami Sea, *Annot. Zool. Japon.*, vol. 4, p. 85—101, pl., 1902.

5. I still consider the validity of this genus extremely doubtful on the grounds given in the "Challenger" Report, p. 78; the type has disappeared, and no second specimen has ever been secured.

6. These two genera may perhaps be identical; for remarks on the question, *see* "Albatross" Report, p. 23.

7. I am not acquainted with any means of distinguishing the females of these two genera, apart from referring them to their proper species.

8. The question whether *Spirula* should be referred to the Myopsida or Œgopsida does not seem to me to be finally settled: in the table above it has been placed in the latter: the question has been discussed by HUXLEY and PELSENEER, "Challenger" Reports, summary, vol. 2, appendix 1, 1895; (French translation, *Bull. Sci. France*, vol. 26, 55 p., 6 pls., 1895), and LÖNNBERG, Notes on Spirula reticulata (Owen) and its Phylogeny, *Festskrift för Lilljeborg*, 22 p., 1 pl., 1896.

9. *See* JOUBIN, Revision des Sepiolidæ, *Mem. Soc. Zool. France*, vol. 15, p. 80—145, cuts, 1902.

10. *Sepioteuthis*, though appearing here in the scheme owing to the form of its fins, really belongs to the family Loliginidæ.

11. The commonest species of these two genera resemble each other so closely that it seems worth while to reproduce here the differential characters given by Pfeffer ("Synopsis," p. 159, 160.)

Ancistroteuthis lichtensteini:—Hinder end of the fin of the adult produced into a long point, so that the fin is longer than broad; the carpal fixing apparatus consists of 9 to 12 suckers and pads; the fifth or sixth proximal hook of the dorsal row is not displaced towards the ventral row of large hooks; the suckers of the arms have no pear-shaped prominence; the pen consists only of the rhachis, and is provided at the end with a small spoon-shaped cone, and a very long solid spine arising from it;

the median rib of the rhachis is bluntly elevated in front, and less cornified than the lateral margins; behind it is narrow, sharply elevated into a keel and more strongly cornified, but scarcely perceptible through the integument.

Onychoteuthis banksi:—Hinder end of the fin of the adult moderately produced, so that the fin is wider than long; the carpal fixing apparatus consists of 7 to 10 suckers and pads; the fifth or sixth proximal hook of the dorsal row is suddenly displaced towards the ventral row of large hooks; the suckers of the arms for the most part have a pear-shaped prominence; the pen in its middle part has a distinct narrow web, which is not connected with the spoon-shaped cone at the hinder end; the solid spine is only of moderate length; the median rib of the rhachis is strongly elevated, rising into a very high and strong keel behind; anteriorly it is much more strongly cornified than the lateral margins, and is clearly perceptible as a sharp dark-coloured line through the integument.

12. The information at present available regarding these two genera is very meagre: I am indebted to my friend Dr. Pfeffer for the following notes regarding them, "*Tetronychoteuthis*: according to d'Orbigny's figure the Paris specimen would appear to have been in the stomach of a Cetacean, so that it no longer possesses either horny rings or hooks, neither has the Hamburg specimen any. I have *inferred* from the form of the fleshy remains that it originally had four rows of hooks. I am now, however, very uncertain on the point for *Lycoteuthis* possesses four rows of suckers with *round rings*. The Hamburg and Strasburg specimens have no longer any horny structures, but the examples from the 'Valdivia' Expedition have four rows with *round rings*; they are, however, rather small. *Lycoteuthis* is an undoubted Onychoteuthid."

13. *See* CHUN, Ueber Leuchtorgane und Augen von Tiefsee-Cephalopoden, *Verh. Deutsch. Zool. Gesellsch.*, vol. 13, p. 67-82, 1903; the genus has not yet been formally diagnosed; no information is yet forthcoming as to its fins, suckers, or other important characters; hence this portion of the key can only be regarded as provisional.

14. *See* "Albatross" Report, p. 42.

15. The type of this genus is *Enoploteuthis polyonyx* TROSCHEL, Bemerkungen über die Cephalopoden von Messina, *Arch. f. Naturg.*, Jahrg. 23, vol. 1, p. 87, pl. 4, fig. 9, 1857.

16. CHUN *(op. cit.)* mentions luminous organs in *Bathyteuthis* but gives no details as to their form or arrangement.

17. This genus is based on a new species from the West Coast of South America, not yet fully described; Pfeffer, "Synopsis" p. 170. Along with it is created another new genus *Stigmatoteuthis* for *Histiopsis hoylei* Goodrich, Ceph. Calcutta Mus, *Trans. Linn. Soc.* (2), vol. 7, p. 15, 1896. I do not see adequate ground for regarding it as generically distinct from *Histioteuthis*.

18. The association of these two genera in the same family is rather artificial, but further information is needed in order to determine their true systematic position.

19. I have little doubt that these two genera are identical, and Dr. Pfeffer informs me that he has independently come to the same conclusion.

20. *See* CHUN, *Rhynchoteuthis*. Eine merk würdige Jugendform von Cephalopoden, *Zool. Anz.*, vol. 26, p. 716, 1903.

21. For a discussion of the nomenclature here adopted *see* HOYLE, British Cephalopoda: their Nomenclature and Identification, *Journ. of Conch.*, vol. 10, p. 197—206, 1902.

22. The fusion of the base of the siphon with the interior of the mantle is also a character of the Cranchiidæ; in *Symplectoteuthis* the cartilaginous joint is retained, but the two elements are fused at all events on one side; in the Cranchiidæ the fusion is more extensive and bilateral and the cartilaginous elements are not developed.

23. According to FICALBI (Unicità di specie delle due forme di Cefalopodi pelagici chiamate "Chiroteuthis Veranyi" e "Doratopsis vermicularis," *Monitore Zool. Ital.*, vol. 10, p. 93—118, pl., 1899) *Doratopsis* is the young of *Chiroteuthis*, but his arguments do not appear to me convincing; his opinion is not shared by Pfeffer, though the late Dr. Jatta was disposed to agree with it (A proposito di alcuni Cefalopodi del Mediterranee, *Boll. Soc. Nat. Napoli*, vol. 17, p. 193—198, 1903).

XXII. The collection of Apparatus used by Dalton, now in the possession of the Manchester Literary and Philosophical Society.

By FRANCIS JONES, M.SC., F.R.S.E.

Since the celebration of the announcement of the Atomic Theory in 1893, additional interest has been taken in the collection of apparatus which belonged to Dalton, now in the possession of the Society, and requests for photographs of it have from time to time been received. To meet this wish the Council resolved on March 15th that photographs of the apparatus should be taken for reproduction in the *Memoirs*, and I was requested to carry out the necessary arrangements. These have now been completed, and the most interesting portions of the apparatus are represented on the following nine plates. Before describing these, it may be of interest to note how the apparatus came into the possession of the Society. Dr. Dalton died in 1844, and by a codicil to his will bequeathed "all his chemical and other philosophical instruments and apparatus" to his friend and pupil, Dr. William Charles Henry, by whom they were presented to the Society. They were placed in a glass case near the door of the meeting room, and some of them were exhibited at the Loan Collection of Scientific Apparatus, held at South Kensington in 1876. Professor Roscoe contributed a note on this exhibit which appeared in the *Proceedings* for 1876, page 77. Subsequently, in 1890, the most interesting pieces of apparatus were placed in new cases in the Library and carefully arranged by Professor Dixon in the positions they now occupy. To both Sir Henry Roscoe and Professor Dixon I am indebted for some of the descriptions of the apparatus which follow.

July 1st, 1904.

PLATE I.

1. Mountain barometer with thermometer attached, made for Dalton by the late Mr. Lawrence Buchan, a member of the Society. The barometer is enclosed in a wooden case (with screw cap at the top) for convenience in carrying.

2. Manometer tube fixed on a wooden board, divided and numbered by Dalton.

3. Barometer made by Dalton consisting of a glass tube bent at the lower end, which is blown out to a bulb to serve as a mercury reservoir. The barometer is attached by wires to a narrow strip of wood with a cross piece at the lower end to support the bulb. At the upper end a paper scale is pasted on, with figures in Dalton's writing. The height of the mercury in this barometer was recently compared with a modern instrument and agreed very closely.

4 and 5. Similar instruments, but containing a little liquid above the mercury, probably indicating that they were used for tension experiments.

PLATE II.

1 and 2. Glass funnels with long stems closed at the ends, graduated by Dalton and used for measuring gases.

3. Graduated bell jar with bent tube attached, for collecting and measuring gases.

4. Graduated bell jar with brass cap and stopcock, for measuring gases.

5. Conical glass vessel containing mercury.

6. Small phial with graduated tube (broken) fitted to the neck, for measuring gases.

Plate III.

1. Small glass lens, wrapped in a piece of paper on which is marked in Dalton's writing "Sun's focus 4·2 inches."

2. Glass specific gravity bottle.

3. A common pair of scales used by Dalton.

4. A specific gravity bottle, 1,000 grains capacity.

5. Lead counterpoise for specific gravity bottle, stamped "175," wrapped in paper marked "bottle balance."

6. Set of brass grain weights from 1,000 to 20, in wooden box (two missing).

7. Glass specific gravity bulbs with figures engraved on each. These are contained in a wooden case on the lid of which is a table of values, "0 = 1·000, 1 = 1·001, 2 = 1·002," &c.

8. Set of brass grain weights from 1,000 to 20 grains, in wooden box.

Plate IV.

1, 3, 4, 5, 6, 7, 8. Seven water thermometers of different materials (stoneware, brass, iron, tin, lead, &c.) for determining the temperature of the maximum density of water. *Nicholson's Journal*, 1804, page 94.

2. Stoppered phial with the bottom cut off and with tube fitting the neck, for collecting and measuring gases.

Plate V.

1. Dalton's pocket balance with beam four inches long and having the pans attached with common string, contained in tin case.

2. Set of four French weights from 10 grammes to 1.

3. Boxes of weights, grammes and grains, the larger ones of brass the smaller of platinum.

4. Leaden grain weights made from sheet lead and stamped with numbers by Dalton.

PLATE VI.

1. A maximum and minimum alcohol thermometer on wooden scale (one bulb broken), made by H. H. Watson, Bolton.

2. A maximum and minimum thermometer used by Dalton and stamped with maker's name, J. Ronchetti, 29, Balloon Street, Manchester.

3. Mercury thermometer attached to strip of wood stamped with the date 1823, apparently made and graduated by Dalton.

4. Mercury thermometer with file marked graduations on the glass stem.

5. Mercury thermometer with long stem and wooden scale.

6. Glass tube used by Dalton for measuring the tension of carbon disulphide vapour. There is a paper scale attached on which in Dalton's handwriting may be seen "Sulphuret. carb." There is a cork at the upper end apparently used for supporting this portion of the tube in a water bath.

7. Bent glass tube.

8. Small glass tube bent at lower end and with paper scale attached.

9. Mercury thermometer attached to strip of wood made and graduated by Dalton and stamped J.D. 1823. The freezing point of this instrument was tested in 1876 by Mr. Baxendell, who found that it had not altered since the original graduation. I have re-tested the freezing point (June, 1904) and find it about $\frac{1}{3}$ of a degree Fahrenheit *below* the mark on the stem.

Plate VII.

1. A differential thermometer.

2. Balance used by Dalton, made by Accum.

3. A wet and dry bulb hygrometer, made by H. H. Watson, of Bolton.

Plate VIII.

1 and 2. Phials containing platinum and amalgam of tin and mercury.

3. A glass alembic.

4. A Florence flask, with cork and valve for determining the specific gravity of gases.

5. A spark eudiometer of thick glass, with copper wires fitted to the neck.

6 and 7. Two Phials, one containing an amalgam of bismuth and mercury.

8—19. Phials, containing respectively iodine, cochineal, mercury, gunpowder, mercury, grana sylvestra cochineal, quercitron bark, resin, mercury, madder, lead and mercury and creosote.

Plate IX.

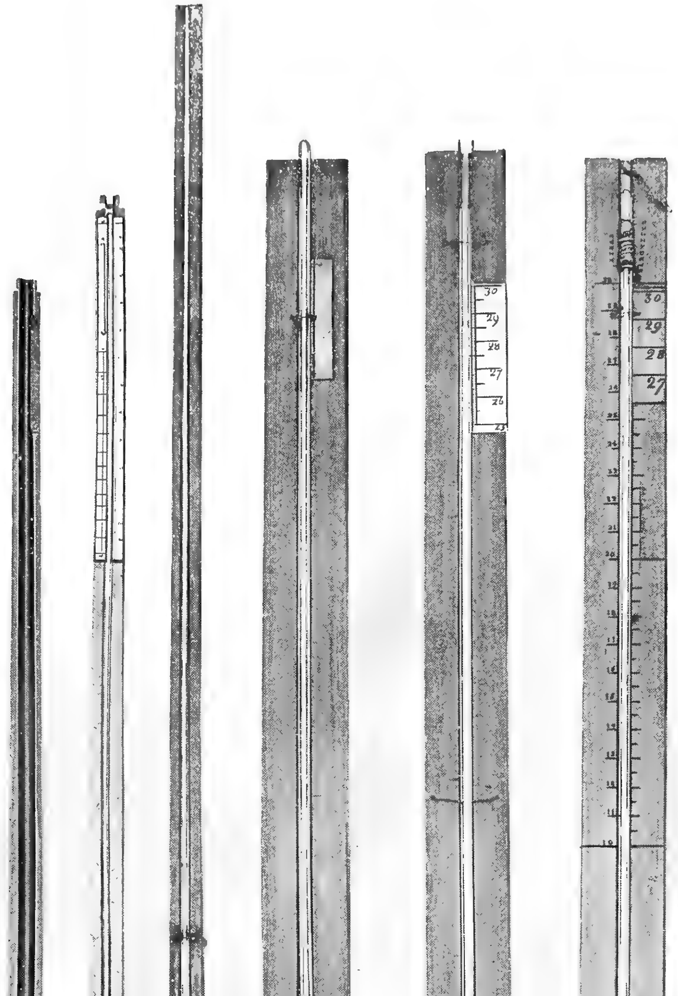
1, 4 and 6. Portions of Pepy's apparatus for the analysis of gases. 1 is the eudiometer, with elastic ball attached. For analysis of air, a solution of nitric oxide in ferrous sulphate is used to absorb the oxygen. See paper by W. H. Pepys in the *Philosophical Transactions* for 1807, page 247.

2. A glass pipette.

3. An earthenware cup used as a mercury bath.

5. Wooden blocks used by Dalton to explain his atomic theory.

7. A glass bottle with brass cap.



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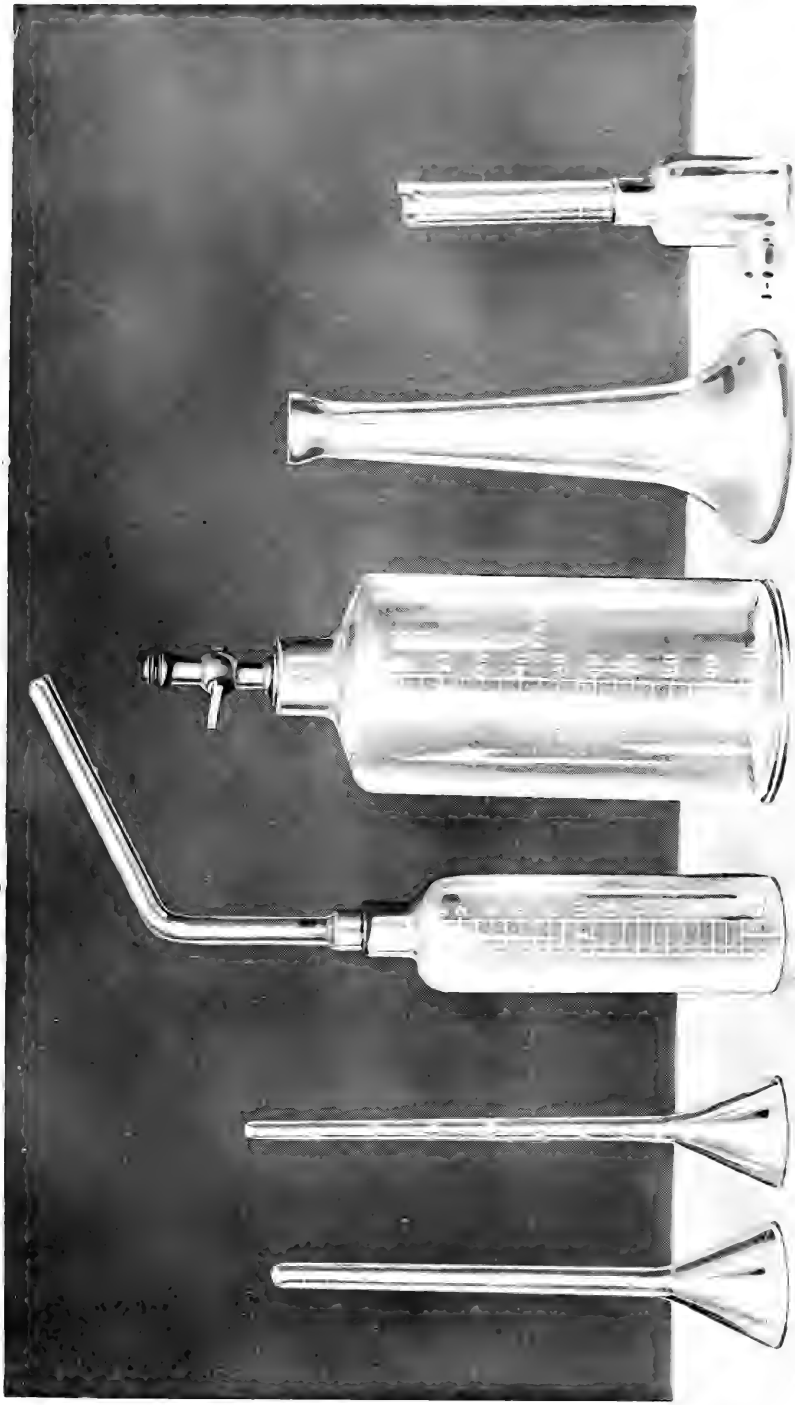

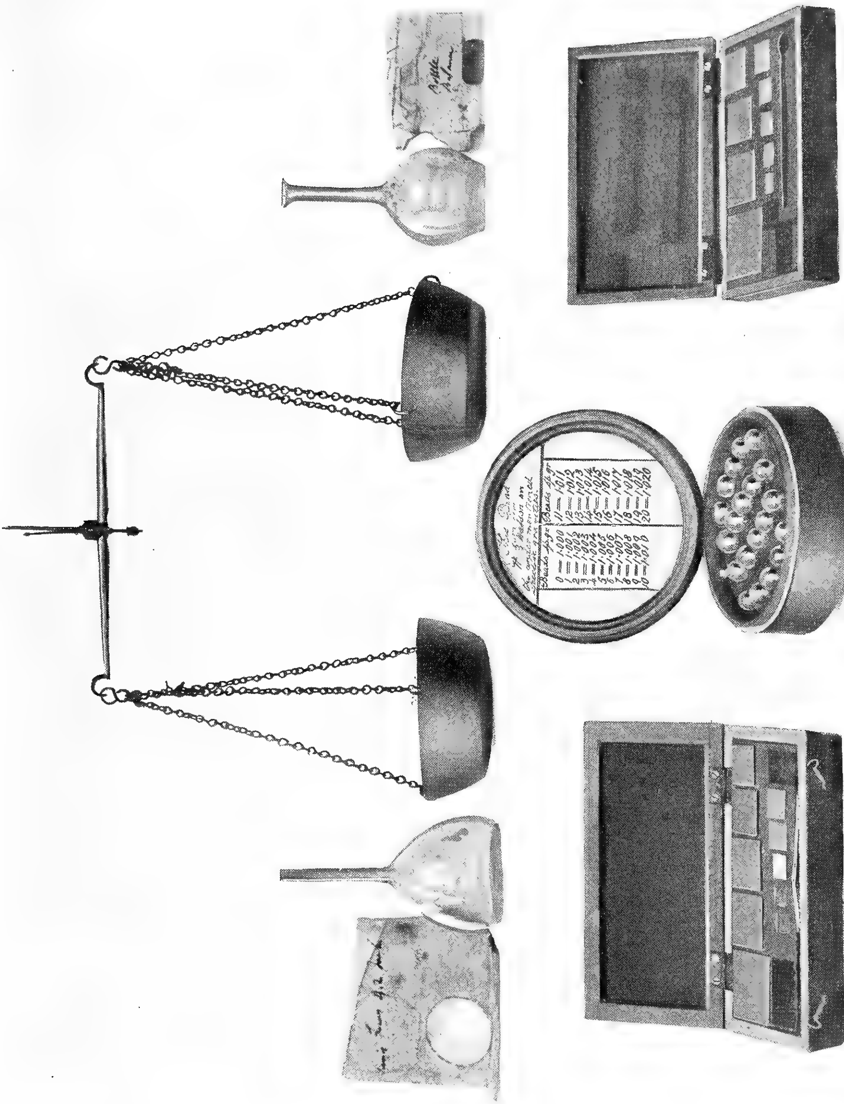

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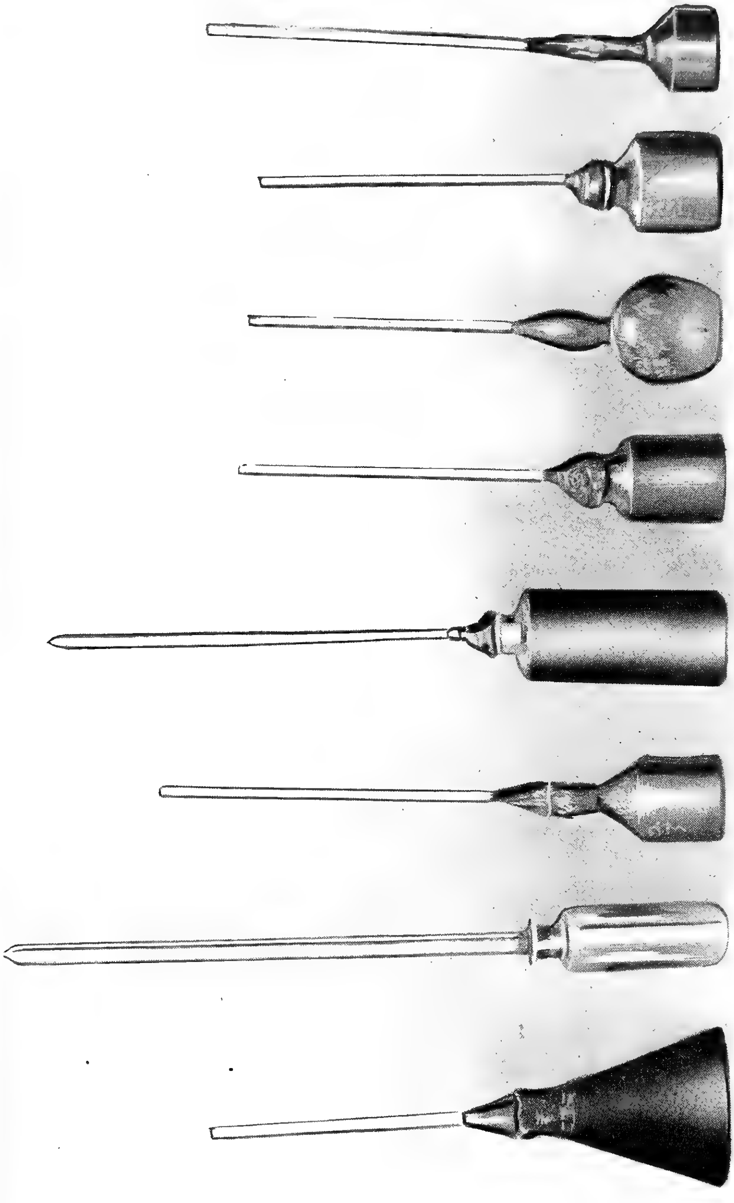

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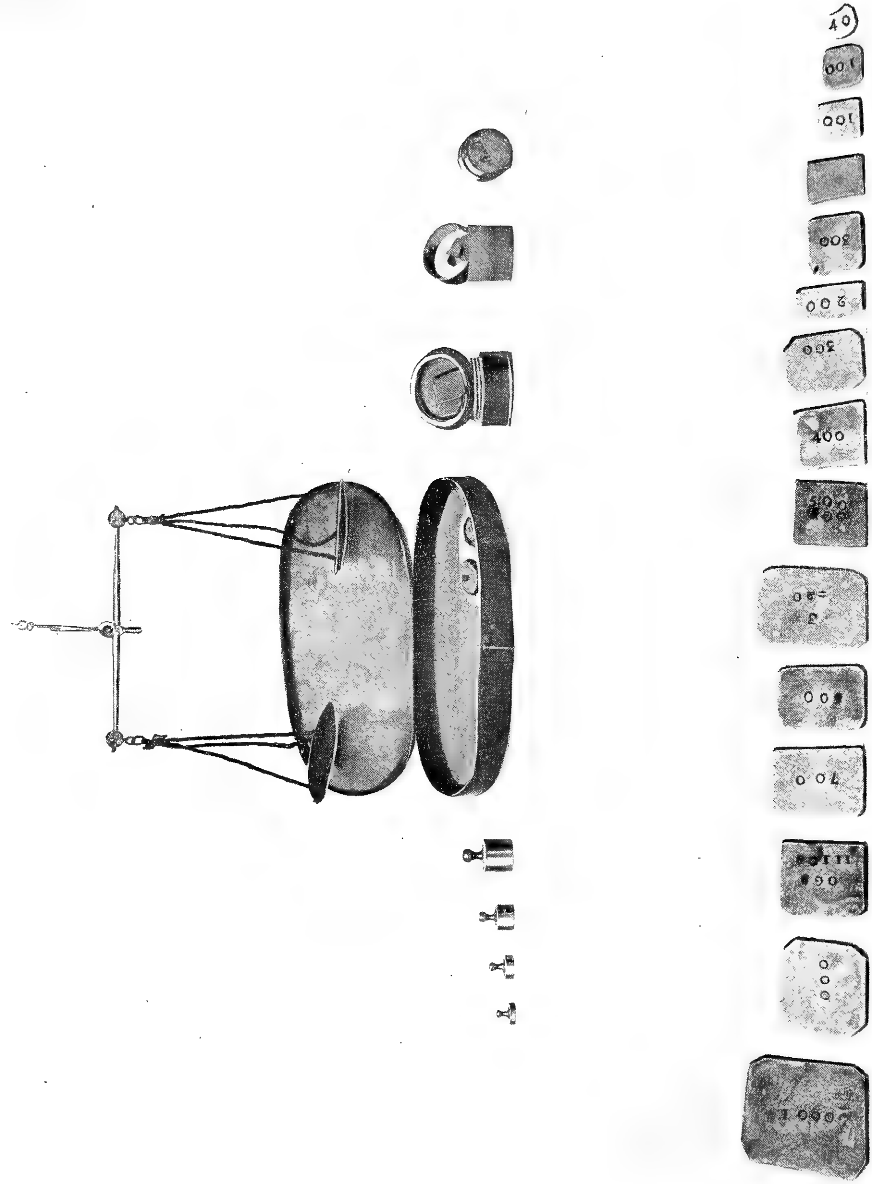

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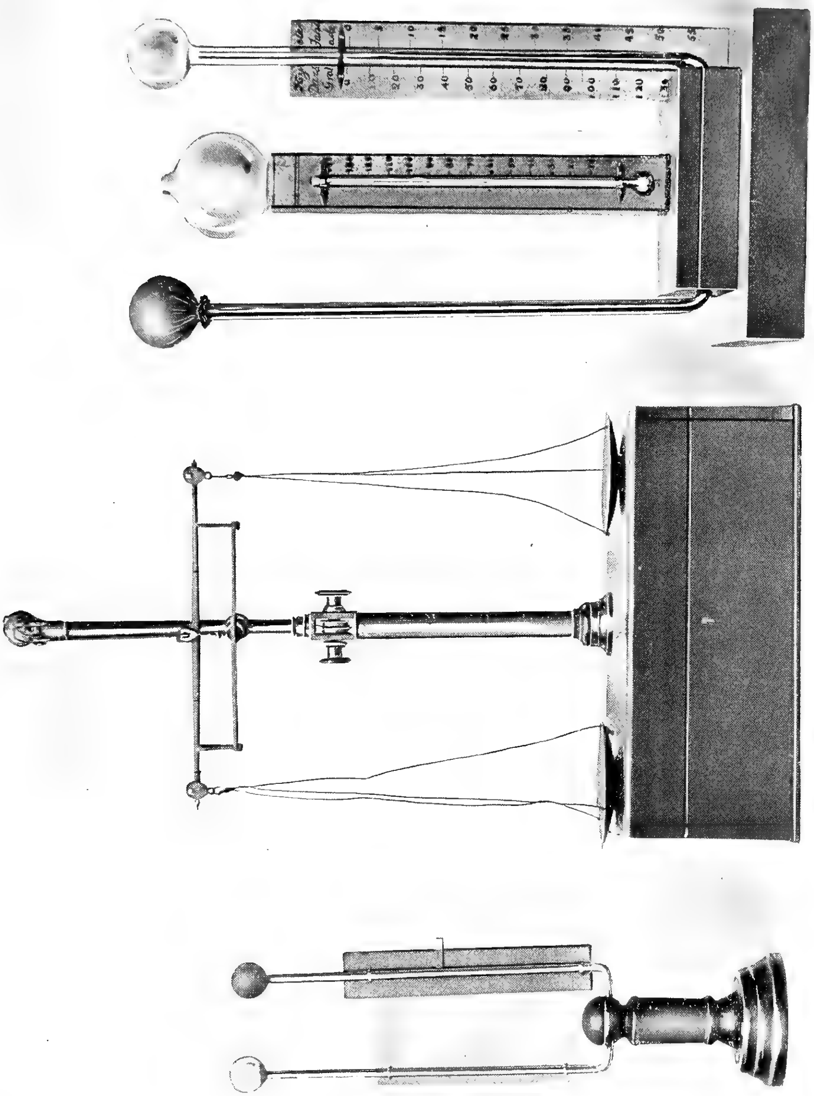

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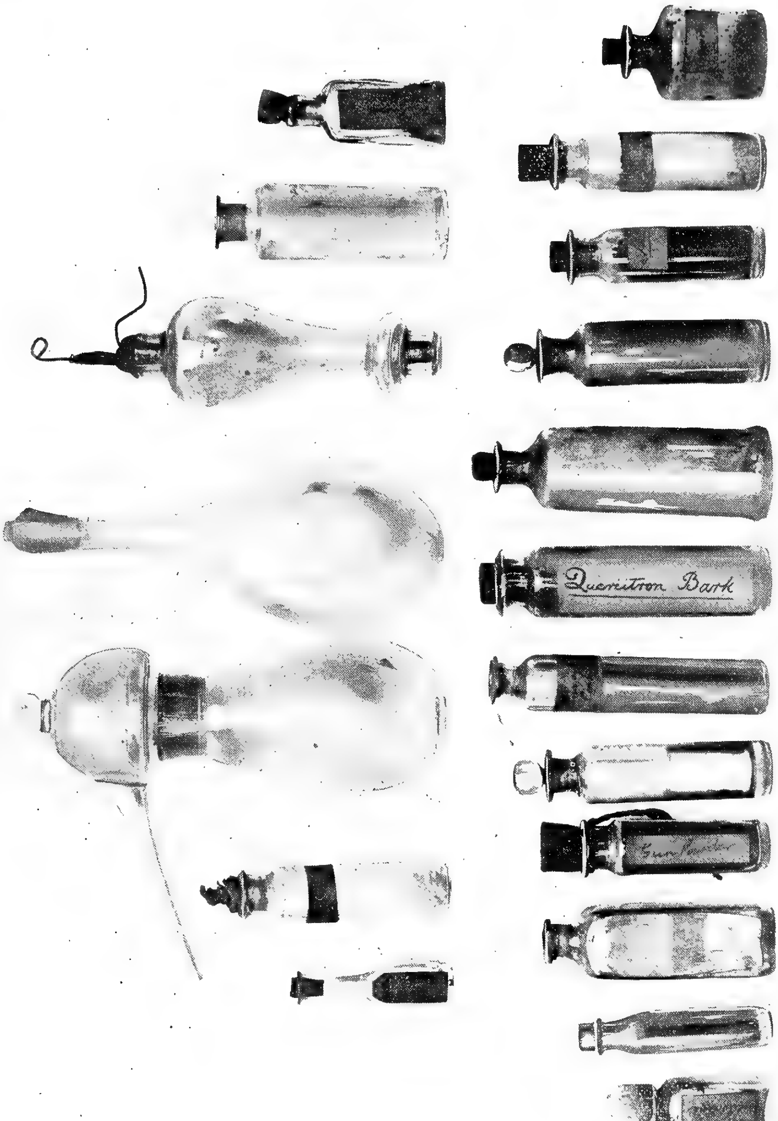

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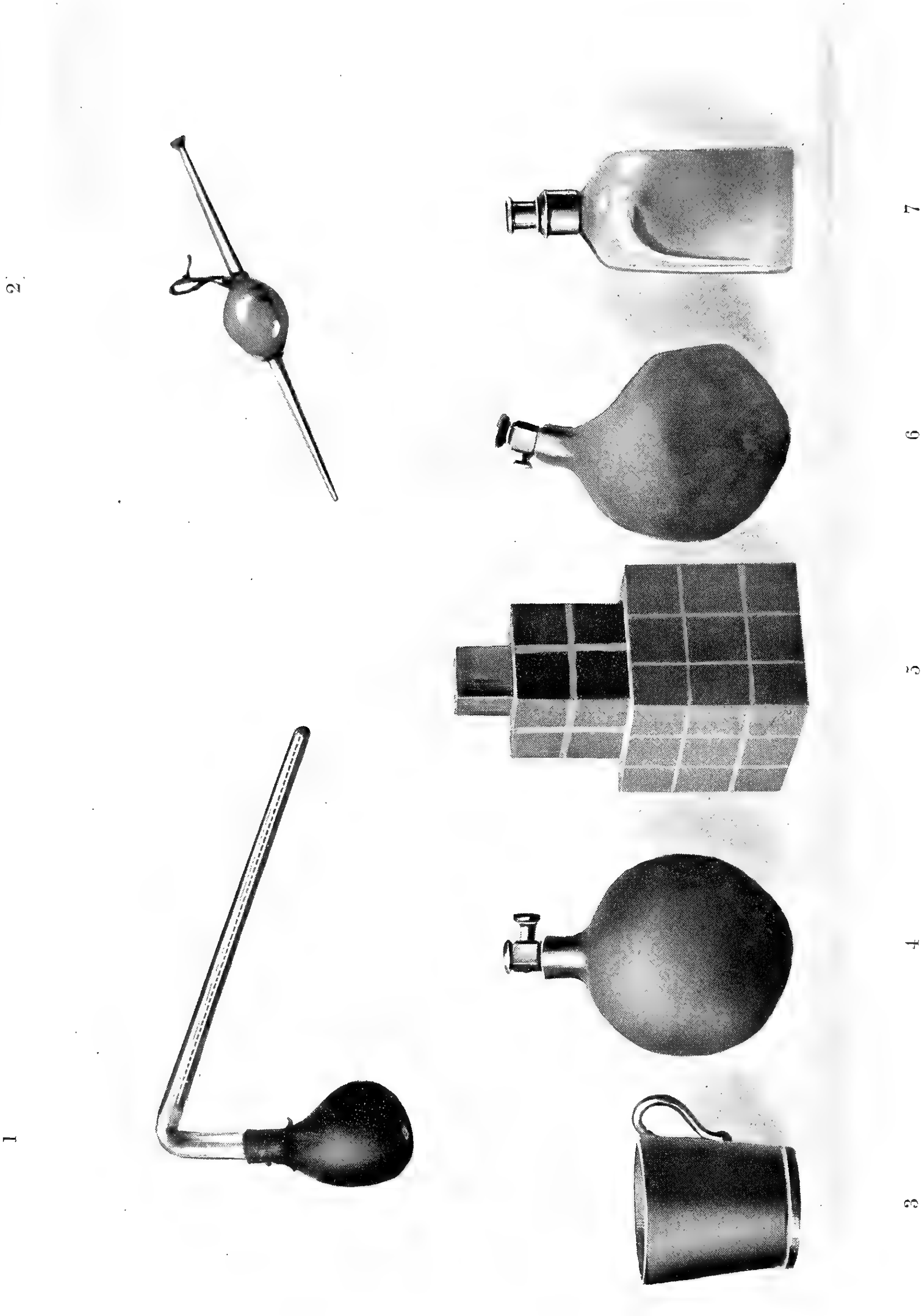
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Manchester Memoirs, Vol. xlviii. (1904), *No.* **23.**

XXIII. Notes on the Falkland Islands.

By RUPERT VALLENTIN.

Received and Read March 15th, 1904.

My first work in Stanley was to unpack my four cases and arrange my collecting things in a small but most conveniently placed room, kindly lent me, as on my previous visit, by the Falkland Islands Company. In less than forty-eight hours after my arrival I had my instruments unpacked, my books, bottles, and reagents arranged, and all ready for work. The little boat I brought with me I moored in a very sheltered spot near the landing stage. However incomplete my arrangements may have been, I consoled myself with the thought that my little laboratory enjoyed one unique distinction, *viz.*, that of being the most southerly zoological station in the world.

Since the date of the first organised visit to these islands, under the command of Bougainville, in 1763, the 'streams of stones' have been one of the most attractive sights to visitors, and are even now looked upon by the settlers with curiosity. Although no geologist, I paid great attention to these 'stone-rivers' during my visit to these islands; and, as they are more numerous on the East Falklands than on the Western island, and very abundant in the neighbourhood of Stanley, I had ample opportunities of examining a large number, and also taking many photographs of them. As these 'stone-rivers' always shew the same structure, a brief description of one of them will answer my present purpose. A 'stone-river' is always found on a hillside or valley, where the slope of the ground can never be called steep; and varies from a few yards to a mile or more in length, and perhaps

July 5th, 1904.

half that distance in diameter. The blocks of quartz-like rock of which it is composed vary very considerably in size, but in form are all very similar, the length generally exceeding the breadth, and they invariably have their ends rounded off by weathering. This fact seems clearly to indicate that these rocks have been detached from their original beds ages ago. These stones are not heaped up in any way, but are always spread fairly uniformly over the ground; giving one the impression that they had been scattered broadcast. A main body or central stream can always be distinguished in every 'stone-river,' while lesser affluents can be observed joining the main stream at almost right angles. Close examination of every 'stone-river,' always shows that the rocks in the upper portion are covered with lichens, and that these lowly plants decrease in quantity as one proceeds down the slope, till within a short distance of the foot the rocks are bare of vegetation.

Darwin[2] and Sir Wyville Thomson[3] are the two most recent authors who have touched on the structure and formation of the 'stone-rivers.' Darwin thinks that their present position is due to some enormous convulsion of nature. Sir Wyville Thomson ventures the theory that . . . "The blocks of quartzite in the valleys are derived from the bands of quartzite in the ridges above, for they correspond in every respect; the difficulty is to account for their flowing down the valley, for the slope from the ridge to the valley is often not more than six to eight degrees," . . . "The process," he continues, "seems to be this: The beds of quartzite are of different hardness; some are soft, passing into crumbling sandstone, while others are so hard as to yield but little to ordinary weathering." In the process of time the harder blocks tumble from their places, and these displaced fragments eventually collect in the valleys and form the 'stone-rivers' such as we find them to-day. My view is, that the stones forming a 'stone-river' had found approximately their present position ages before the peat was formed. Owing to changes in the climate, vegetation spread over the land, and the 'stone-rivers' were perhaps quite covered. Now, owing to a fresh change in the climate, a rapid denudation is setting in; and, speaking geologically, at no very distant date the whole archipelago will be nothing more or less than a barren heap of rocks and sand. On digging into the peaty soil at the foot of every 'stone-run,' rocks identical both in form and structure to those already exposed can be uncovered, while openings in the soil varying both in size and depth can be detected. On probing some of these holes with a stick, a stream of water can frequently be touched; this water having percolated through the rocks from the ground above. The ground, for some little distance beyond the termination of every 'stone-run' is always dangerous to a horseman, owing to the presence of holes of various sizes caused by the soil having been removed by the underground stream of water. After a heavy rainfall the hillsides simply stream with water, and the many rivulets carry down in suspension vast quantities of soil into the numerous creeks and harbours round the islands. Vessels moored in Stanley harbour always experience great difficulty in weighing their anchors after a stay of any length of time, owing to the depth they have sunk in the mud. Recent investigations have shewn that upwards of seventeen feet of mud had to be passed through in the middle of Stanley harbour before bed-rock could be touched. This deposit all came from the surrounding land, having been brought thither either by peat-slips, several of which have happened within living memory, or washed down by the rains.

One can always find in every 'stone-run' islets of vegetation varying in extent placed close to or some little distance from the edge. In those islets where the separation has been recent, the various plants of 'diddle-dee' (*Empetrum rubrum*) and fachina bushes (*Chilabothrium amelloides*) appear to be flourishing ; but in examples farther removed from the edge of the 'stone-run' and where the separation has taken place long ago, the sole survivor will be a large balsam-hog (*Bolax glebaria*), which owing to its long tapering root piercing the soil far beneath, has been able to obtain sufficient nourishment to keep it alive when all its neighbours have perished. Without much trouble one can find on every large 'stone-run' these islets in all stages of formation. The fact of the lichens being so abundant on the upper rocks and gradually decreasing both in numbers and luxuriance as one passes to the foot of every 'stone-run' seems to me unquestionable evidence that the rocks have been laid bare gradually as the surrounding land has been removed by the elements.

There was one rather curious feature I observed at Port Louis relating to the burrowing habits of the 'ship-worm' (*Teredo palumata*). Although wood is very scarce in this region, there being no trees on the Falkland archipelago, and only a few slight scattered piers near the wool-sheds ; yet, on placing a piece of timber in the sea for a short time anywhere round these islands it soon becomes riddled with the borings of this destructive mollusk. I can only suggest that quantities of free swimming larvæ of this species are wafted thither by the current from Cape Horn, where dense forests abound, and where vessels when at anchor in the many estuaries nearly always haul up with their anchors pieces of wood of varying sizes infested with *Teredo palumata.* In front of Mr. Packe's wool-shed was one of the usual light landing-stages, which always form one of the adjuncts to a well appointed shearing-shed, down the centre of which were laid light rails to facilitate the embarking of bales of wool. The framework of this jetty was in this instance built of light pieces of wood of various lengths, but measuring 3 in. × 4½ in. in thickness. On examination, I was astonished to find all the submerged pieces of wood forming this structure riddled with the borings of this destructive mollusk. According to my observations, *T. navalis*, the species found in England, invariably begins its perforations at the cut end of a beam, and so at the Falmouth Docks and elsewhere experience has taught the engineers that the life of a beam of timber may be considerably prolonged by driving a number of short iron nails in the exposed end of each submerged piece of timber, the rust caused by the action of sea-water tending to keep away the larvæ for a considerable time. I examined many pieces of the timber from this jetty which had been removed owing to their rotten condition, and also made as close an examination as circumstances would allow me of the wood-work during low-water, and was astonished to find that in no single instance did the larvæ of *T. palumata* commence their burrows at either end of these beams, but always obtained an entrance by small circular openings one-tenth of an inch in diameter, which were scattered irregularly over each piece of wood. On digging into these beams with my hunting knife, I found them riddled with the tubes of *T. palumata*, and quite fragile in consequence, but in every instance the ends were intact.

Leaving Stanley in a small schooner on the 20th January, 1900, I sailed to the north-western extremity of the West Falklands, making my head-quarters at Roy Cove, where I was most hospitably entertained by Mr. Wickham-Bertrand and his family. On the morning of the 23rd, we landed at Hill Cove, and rode about a mile and a half to Mr. Miller's house, where we were kindly entertained till the day following. This morning was most beautiful; the bright sun, the cloudless sky, and keen fresh air gave new life to us all. It was not low-water till 3 p.m., so I started after an early lunch to walk to two little islands, known as Bense Islands, about four miles distant, at the extreme end of the bay. I was agreeably surprised to find the scenery and vegetation on this portion of the Falkland archipelago far more attractive than that in the neighbourhood of Stanley. The high hills skirting the shore, and the pleasantly green islands covered with Tussac (*Dactylis cæspitosa*) scattered over Byron Sound looked most beautiful; while on the main-land the high grass, and still higher Fachina bushes (*Chilabothrium amelloides*) gave an agreeable finish to the landscape. On my way from the house the Fachina bushes were at least four feet in height, and presented an almost solid border on either side of the rough track which led to the sea-shore. Over a considerable portion of the foreshores I walked with some difficulty owing to the softness of the mud; but later, the ground became firmer, till on nearing the end of the bay, I got to a sandy beach, and afterwards the firm shingle, and stepped along merrily. Attached to the stones, which were more or less covered by this soft deposit, were quantities of two species of mussels, *Mytellus edulis* and *M. magellanicus*. With these a few *Patella ænea*, *Siphonaria lessonii*, and *Photinula expansa* were also noticed. Only two dead 'clams' (*Chione exalbida*) and broken Volute shells were seen during the whole afternoon. There was a series of most attractive rock-pools left exposed during low-water on the spit of land between the point and the islands. Here the fauna was richer. Besides a considerable increase in the numbers of the abovementioned species, were quantities of the singular crab, *Halicarcinus planatus*, and the little crustacean *Ectinosphæra gigas*. A species of *Melobesia* also fringed these pools, while in their crevices were numbers of worms new to me. Specimens of these were secured and preserved in formalin. The prince of grasses, the Tussac grass (*Dactylis cæspitosa*), was quite high on the islands, and I had some difficulty in forcing my way through its dense growth. I did not find any nests either here or during my return to the house. This rather astonished me for birds were most abundant.

The gardens in this portion of the Falklands are far more fertile than those elsewhere on this archipelago. This is partly due to the greater depth of soil, but chiefly to the vegetable fibre formed by the decaying Tussac. I observed the usual garden vegetables flourishing in the cultivated ground round Mr. Miller's house, but they were all enclosed by high thick hedges of furze (*Ulex europæus*) which protected the tender plants from the furious winds. The soil in this cultivated spot had to be treated very generously before vegetables fit for table purposes could be raised. By spreading over the land from time to time vast quantities of refuse from the boiling-down establishment at Hill Cove, Mr. Miller has been able to cultivate successfully vegetables which it would have been quite impossible otherwise to have produced.

I managed during my visit to make a fairly exhaustive examination of the littoral fauna exposed during low-water in the various creeks and inlets which are scattered along this section of the coast. The sandstone cliffs fringing the ocean, and varying from 50 to 100 feet or more in height, effectually prevent any continuous stretch of shore being left bare by the tide. On these occasions, during shore collecting, I only preserved such specimens as I could not identify, but always entered in my note-book on the spot all the forms seen. I am satisfied that my notes, together with the specimens collected, would give a fairly representative list of the invertebrate fauna to be found on that section of the Falklands. I may here mention that in spite of a most diligent search I never saw a single medusa in the sea from the day I left Stanley till I returned. Taken as a whole, I was not astonished to find the littoral fauna on this portion of the Falkland archipelago a poor one. This fact is in a great measure due to the heavy seas from which no inlet or cove, however sheltered it may appear to be, is protected. Under such conditions only the strongest forms are able to hold their own. Besides, all the creeks receive the surface drainage from the surrounding country, so the amount of fresh-water flowing through them to the sea must, during the winter season, be very great.

The common shore mollusks, such as *Siphonaria lessonii*, *Patella œnea*, *Mytellus edulis*, and *M. magellanicus* were abundant everywhere. *Crepidulata dilatata*, *Euthuria antarctica*, and *Photinula expansa* were scarce. The 'whelk' (*Trophdon geversianus*) was not found alive along any of the foreshores, specimens of these were only to be found after gales of wind. *Fisurella picta* and *F. polygonia* were both scarce. *Acmœa cœciliana*, *Chiton setiger*, and *C. atrata* were all very scarce indeed. *Teredo palmulata* was present in all the submerged timber. In crustacea, *Halicarcinus planatus* was very scarce indeed all along the the southern shore of this promontory. *Ectospheromia gigas* abounded everywhere, especially in Whaler Bay, where it occurred in swarms. I found one egg capsule of a species of *Elasmobranch* on the beach near Roy Cove.

Annelids of various species were very numerous in the crevices of a species of *Melobesia* which abounded in Roy Cove. Of all these I preserved numbers, and with them some specimens of *Arenicola*, probably *A. claparadii*, but did not examine them very closely when I gathered them.

The sides of all the estuaries and coves on this portion of the West Falklands are almost fringed with the bushes of the attractive 'Falkland box' (*Veronica decussata*). These beautiful shrubs were in full flower at the time of my visit, and the flowers besides being beautiful possessed a delicate aroma, which was most pleasant, for it perfumed the air for some distance I noticed that several specimens of this box had thin roots and branches submerged more or less in sea-water during the spring tides, but this did not appear to affect them in anyway. Perhaps an occasional wetting in salt-water might act as a fertilizer. This plant is successfully employed as a shelter from the winds, numerous bushes placed closely together forming a splendid hedge in many of the gardens on these islands. Some of the largest specimens of a beautiful fern, *Lomaria magellanica*, grew in the crevices of these cliffs, some of the fronds being quite three feet or more in length. The roots of these were quite six inches in diameter, and the whole plants were vigorous.

About eight miles to the south-west of Roy Cove is a very pretty land-locked harbour known as Whaler Bay. This spot was another of the great assembling places of the sealers during the first half of the last century. Besides the excellent shelter, there is an abundance of fresh-water to be obtained from a stream flowing into its extremity, and peat can be cut from the hill-sides. Here I spent a pleasant day with Mr. Bertrand, collecting plants and examining the foreshores at low-water. On our way thither, we passed through a very picturesque valley in which grew numbers of a pretty tree fern (*Gleichenia cryptocarpa*). This fern is very local, and appears to be restricted to one or two places on the West Falklands. I also noticed on this occasion some of the largest specimens of that singular plant, the Bog balsam (*Bolax glebaria*). Although very common throughout the whole archipelago, it is very seldom one finds a plant of this species of any considerable size, such as were to be found in the early days of the colony. It is well known to the residents on these islands that on bruising or cutting the hard exterior of this plant, so as to allow the rain to lodge in the crevices, a rapid decay soon follows, and within about a twelve-month nothing but a heap of mould and fibres is left of a plant which took years to attain its previous size.

Owing to the abundance of sheep throughout these islands, and the large areas covered by such unprofitable plants as the 'Bog balsam' (*Bolax glebaria*), 'Fachina' bushes (*Chilabothrium amelloides*), and 'Diddle dee' bushes (*Empetrum rubrum*), and the ferns *Lomaria alpina* and *L. magellanica*, these animals are at times hard pressed to find sufficient grass to eat, and in their close search for food run over and bruise the smooth surface of the Bog balsam plants, and so they are easily destroyed.

There are but few wild cattle left now on these islands. Those used for domestic purposes are almost as tame as the cattle in England, and are kept close to the settlements. The old breed of wild cattle, perhaps the lineal descendants of those imported by Bougainville in 1767, are almost extinct, a few of them are yet to be found in the neighbourhoood of San Carlos on the East Falklands. On some of the outlying islands where there is little else but Tussac grass a few cattle are allowed to roam, and when beef is wanted a visit is paid them, and two or three are shot. During my visit to Roy Cove, I tasted some beef from cattle reared under these conditions, and I can certainly affirm that the flesh was as superior to common beef as three-year-old southdown mutton is to the ordinary mutton purchased in London. From several conversations I have had from time to time with the earlier settlers on the Falklands, it must have been rather a risky matter to attack in the open a Falkland Island tauro. A pair of horns together with the frontal bones removed from the head of one of these animals, and now in my possession, measures 39½ inches from the extremity of one horn to the other. A truly formidable beast.

The promontory which forms the southern boundary of Whaler Bay is separated from the next paddock by a wire fence. On this neck of land I found the wild celery (*Apium graveolens*) growing most luxuriantly. A very large clump of our English furze growing not far above high-water mark at once attracted my attention. It was the invariable custom of the Government surveyors to plant several of these shrubs near their camping grounds when they were surveying these islands, and this fact accounted for its presence in this remote spot. This plant *Ulex Europæus* does not seed itself on these islands.

During a visit to West Point Island where Penguin rookeries abound I examined several scattered burrows occupied by the Jackass Penguin (*Spheniscus magellanicus*), before we reached the first Gentoo rookery (*Pygosceles tæniata*). Here we found some thousands of these birds, with their nests on the hillside, amidst dense growths of Tussac. Most of these birds had a couple of recently hatched young ones, but in some instances they were almost full-grown. A very few nests were observed with a couple of unhatched eggs in them. It was interesting to notice that the nests of these birds were constructed entirely of Tussac grass, gathered from the plants hard by. The ground all round the rookery was trodden down and saturated with filth, the strong ammoniacal smell, which is always the first thing noticed on approaching a Penguin rookery, being very apparent. In one of these nests, I discovered a couple of stones, evidently placed there by the owners, which, as I afterwards found, weighed 2¼oz. each. On pointing these out to my companion, Mr. Felton, he told me he had frequently observed a Gentoo select a stone from the beach, and on picking it up start for its nest. This act seems amongst these birds an open declaration of war. On his way thither all his neighbours attack him, and try to obtain possession of this coveted stone. After a free fight, one Gentoo would succeed in placing it in his nest, and then the stone was instantly forgotten by the others. All the stones I removed from the nests were far too large to pass down the œsophagus of a bird of this species ; besides, they were coated with filth and were dark in colour. I could not satisfy myself why these birds collected them. If these stones had been bright in colour, and glistened in the sunshine, one would at once attribute this collecting trait to an æsthetic taste possessed by these Penguins, but all I examined were dark in colour and dull-looking.

On passing a short distance along the sloping ground, the hillside became steeper, and numerous rocks and boulders appeared. Here we found an enormous rookery of birds, and they formed an almost unbroken colony along the cliff for at least half a mile. There were three species of birds present—'Mollymauks' or lesser Albatross (*Diomedea chlororhynca*), 'Rockhoppers' (*Eudyptes chrysocome*), and 'Shags' (*Phalacrocorax imperialis*)—and they appeared to live together in perfect harmony. Under these circumstances, it is difficult to estimate their numbers. The 'Rockhoppers' were by far the most numerous. They swarmed everywhere, and were so fearless that I had to push them on one side with my foot to photograph a group successfully. On walking slowly through these birds, one of them, with more courage than discretion, would attempt to dispute the right of way, and make a vicious peck at one's legs. But these assaults were soon met with a kick, which sufficed for that poor bird; but as others were usually at hand ready to take his place, one's rate of progress was always slow. There was not any trace of any of these birds' nests left anywhere. The whole side of the cliff was a semi-liquid mass of slush, with rocks of various sizes scattered about. Another striking feature was the number of dead and dying birds about this rookery. Some of the Penguins were maimed, having lost the greater part of a wing, while others were bleeding from various parts of the body. Mr. Felton informed me that these maimed birds had probably been mauled by seals or sea-lions on their way to the landing place at the base of the cliff, numbers of these beasts frequenting this island. Later, I saw a 'Rockhopper' land in a very sorry plight; he was bleeding from various parts of the body, and in a few moments expired. In an instant a skua-gull (*Megalestris antarctica*), to whom nothing comes amiss, flew down and began to tear it in pieces. On another occasion, when visiting an enormous rookery of Rockhoppers in Berkley Sound, where seals and sea-lions are very scarce, I did not detect a single maimed bird in the whole assembly, and only one sick individual. This bird greatly excited my curiosity, and, much to my regret, I could not examine him very closely, owing to the inaccessible place he had chosen to spend his last hours in. The whole of the chest of this bird was yellowish, instead of white. The bird was most emaciated; the keel of the sternum was plainly visible through the thick feathers clothing the chest.

Intermingled with these Rock-hoppers, but always perched near the edge of some steep slope, from whence, with one spring, they could launch into the air, were scattered couples of the 'Mollymauk' or lesser Albatross (*Diomedea melanophrys*). On our approaching a pair of these birds, they would put their heads together and move them up and down, as if criticizing the personal appearance of the visitor, but never attempt to molest him, although a very severe bite could be inflicted with their powerful bills. Indeed, these beautiful birds were so harmless, that I stroked several with my hand, while admiring the softness of their feathers and their spotless condition. But I fear my remarks, if understood, were not appreciated, for they always turned their heads away as if disgusted; giving vent at the same time to low crooning sounds, which, if not loud, were deep and singularly suggestive of bad language. The nests, which were numerous, were most interesting. Each was invariably made of the semi-liquid filth abounding in the rookery. This evil-smelling compound was deftly gathered in the bill and placed where it was required by the birds. I observed one Mollymauk carefully repairing a broken side of its nest in this manner. I was greatly struck with the fact that although she was handling such a foul mixture, yet she dexterously managed to keep herself spotless. My impression is that these birds are most particular about their personal appearance, and resemble in this respect the Emperor Penguin (*Aptenodytes Forsteri*). An individual nest is cylindrical in outline, and measures sixteen inches in diameter at the top, a slight concavity, three inches in depth, occupying the centre. Speaking generally, the nest is raised sufficiently from the surrounding ground so as to enable the sitting bird to spread its wings and launch itself at once into the air. I noticed several nests which had doubtless been occupied for two or even three seasons. These nests distinctly shewed an annular marking where the structure had been built on, and in some few instances three rings were noticed, shewing that the nest had been used for three seasons. This fact seems to shew that Mollymauks pair for life. Another striking feature about them is that the female lays only one egg during each season, and if this is taken or destroyed the parent birds amuse themselves playing at housekeeping till the following April, when they fly away till the succeeding October. There was abundant evidence to prove this statement, numbers of empty nests being visible around me, the eggs having been removed during the previous November. To give some idea of the abundance of these birds on some of the more remote islands in the southern seas, the following incident may be of interest. Soon after my arrival in Stanley, a sealer arrived at that port with upwards of 10,000 eggs laid by this species. The captain had experienced very bad luck during his sealing expedition, capturing only thirty seals during a three months cruise. Not wishing to return empty-handed, he visited the Beauchenes, an isolated group of rocks about a hundred miles due south of the Falkland archipelago, and soon loaded his schooner with Mollymauks' eggs. These eggs were retailed in Stanley at 12/- a hundred, and soon found a ready market in a place where so little variety of food can be purchased. I bought a number of them, and had them cooked in a variety of ways, and found them most delicious, being in my opinion vastly superior to Penguin eggs, no fishy flavour being perceptible. One of the crew of this schooner assured me that there remained thousands of nests of Mollymauks on the island still undisturbed, only those nests near the landing place having been robbed of their contents. This I can quite believe, seeing that the island is stated in the *South American Pilot* to be......" about half a mile across." To carry a number of such eggs across a rocky island without breaking them would be almost impossible.

The few young birds of this species which were hatched from the eggs laid during the previous November were very attractive. They were covered with a layer of fine down of a uniform lavender-grey colour; the bills being almost black. These young fledglings were most pugnacious, and would invariably stand up in the nest on one's approach, and snap their bills at the intruder. The most striking feature about these birds was that each was far too large for its nest, and as they could not fly they seemed most helpless, and never appeared even to step from their homes. These young Mollymauks were all about the same size, and measured about 14 inches in height when standing erect. On leaving this rookery, I passed on and soon arrived at the edge of a precipice, with an almost vertical wall of rock at least 400 feet above the sea. Scattered along the edge of this cliff were numbers of nests of the same species of Mollymauks, and as these birds were numerous, I thought it would be a good opportunity to test an experiment made by Captain Carmichael, at Tristam da Cunha. According to Professor Mosley,[6] this gentleman......" threw one of these birds over a cliff, and saw it fall like a stone without attempting to flap" its wings. With Mr. Felton's assistance, we both simultaneonsly seized one by the neck and wings, and at a given signal threw it over this precipice. As soon as the bird was free, it spread out its wings, and soared away none the worse for the experiment. As several additional trials were made during the afternoon with invariably the same results, I can only suggest that the Mollymauks experimented on by the gallant captain must have been a different species to those frequenting the Falklands.

On descending to the 'Rockhopper' rookery, we found it to be very similar to those visited during the morning, only the birds appeared to be more numerous, this perhaps being due to the absence of the Tussac grass. A small stream of fresh water ran through the centre of this rookery, and roughly divided it into two parts. On descending the face of this cliff, by following the narrow path made by these birds to the beach, we came to a boulder-strewn cove, at one end of which a sloping rock, many thousands of tons in weight, sloped gradually to the water's edge. Here we rested, and watched for some time the Rockhoppers returning from their feeding-grounds. There was a light breeze blowing into this recess, and so these birds had to watch for a smooth interval between the waves before attempting to land. Suddenly numbers of heads would appear popping up from the water about fifty yards from the rocks; then, without any warning, a number of Penguins would suddenly shoot out of the sea on this rock just after a wave had broken, and scramble up the slippery surface out of harm's way as fast as possible; the rudimentary wings being used for balancing. But for some of them the danger was not over. Some birds would miss their foothold, and stagger about on the slippery rock; others would stand still, apparently dazed, as if the sudden change from an aquatic life to a terrestial one was too much for them. All these birds would be immediately swept away by the following wave, and probably be knocked against the rocks. The behaviour of one Penguin amused me greatly. He had evidently made several attempts to land unsuccessfully, and so was tired; at last he managed to scramble up, as he thought, out of harm's way, and at once commenced to arrange his feathers. Suddenly, a wave much larger than any of the previous ones appeared right above him and ready to break. In an instant the bird grasped the situation, and taking a plunge into it escaped without injury.

In some instances, these Penguins appeared to quite miscalculate the right time to come on shore, viz., in the dead water between two waves. They would land, or rather be thrown, on shore on the crest of a breaking wave, and would be flung up the sloping rock, and struggle out of harm's way as best they could. I carefully timed with my watch the average number of birds landing, and found the number to be as near as possible ten a minute. This was at 4 p.m. Mr. Felton informed me that about 2 p.m. every day is the time when the greatest numbers come on shore.

It was here and also higher up the cliff on the track used by these birds that Mr. Felton pointed out to me a very interesting feature. The smooth surfaces of the rocks over which these Penguins had passed for countless generations were not only polished, but were marked by lines of irregular shape and outline by the nails at the ends of their feet. These scratches were usually about three inches in length, and the deepest of them about a quarter of an inch. On observing some of these 'Rock-hoppers' more closely, I noticed that in every instance those birds placed the whole of the foot on the ground, and that the nails at the end of the feet were always at right angles to the rest of the foot. Hence, when these birds were walking on the soft guano-soaked ground, the impressions left by their feet always shewed three sharp nails at the end of each foot most distinctly. After admiring groups of these birds preening their feathers, and washing themselves in the fresh rain-water which had collected in some of the rocks, we retraced our steps to the cliff above, passing on our way numbers of Mollymauks.

One recess, which seems to have been formed by human hands, had been taken possession of by about a dozen couples of these beautiful birds, and no 'Rockhoppers' were with them. Elsewhere, both species seemed to live in perfect harmony.

At the eastern corner of this rookery a dim outline of a circular bank, about twenty paces across, could be traced, an opening about three feet in diameter being left nearest the rookery. This, Mr. Felton informed me, was the remains of a corral built by the sealers years before the island was inhabited. The method employed by those men for collecting the birds was most cruel. About 200,000 'Rockhoppers' were driven into this enclosure, and the entrance closed. Most of the birds soon died for want of air, and the few survivors were knocked on the head by the sealers. The bodies were later boiled down for the oil they contained, and as each bird was calculated to yield about a pint of oil, the amount collected must have been very considerable. This fluid was poured into casks, rolled to the nearest beach, and rafted off later to the schooner and stored in the vessel's hold. After fruitless enquiry from many people in the Falklands for what purpose this oil was used, I at last found an old sealer in Stanley, who had spent many years cruising round the Falklands and Cape Horn, who told me that this oil was sent exclusively to France and used there in the soap manufactories. The market value of it was about £20 a ton. Fortunately substitutes have now been found, and so these interesting birds are not molested in any way.

During our passage from this island to the mainland our course lay through an extensive tidal stream. When we had gained about the centre of this I suddenly observed the water teeming with small red crustaceans, belonging to the *genus Galathœa*, but which are known to the dwellers of these climes as "Whale food." Almost simultaneously with the appearance of these crustaceans appeared numbers of "Jackass" and "Rockhopper" Penguins, all of which were busily engaged in catching and devouring them with avidity. I had frequently observed in the undigested morsels cast up by these birds on West Point Island and elsewhere the remains of a species of crustacean; now I was pleased to be able to see both species of birds actually devouring the living animals.

FAUNISTIC NOTES.

INSECTA.

COLEOPTERA.

Beetles were not numerous. I find my collection contains five species, they are as follows:—

Lissopterus quadrinotatus, Waterhouse. Common everywhere in the peat.

Emalodera multipunctata, Carbis. Evenly distributed all over the islands. Usually found under stones.

Listroderes. 3 species.

HYMENOPTERA.

I captured one windy day in a sand-pit, some miles from Stanley, a very brightly coloured insect. It was struggling amid a heap of fine sand, and seemed to have been blown thither by the wind. A gentleman in the insect department of the British Museum, writes, concerning this specimen, as follows: "This may be a variety of *Mischocythurus smithii* de Saussure, but it is impossible to tell because of the wings being deformed. *M. smithii* ranges from the Brazils southwards to Patagonia."

Moseley (*loc. cit.*) mentions finding some dipterous insects near Darwin harbour during the visit of the "Challenger" to these islands. These insects were . . . . "a species of fly (Muscidæ) and a species of gnat Tipulidæ. The fly has small rudimentary wings. . . . . The gnats which I found also cannot fly, having even smaller rudiments of wings than the flies." I found a dipterous insect in abundance amid some sand-hills near Hookers Point, Stanley, towards the end of February. The wind was blowing the sand along in clouds, and partially burying these flies as they were being swept hither and thither by the blasts. Fly they could not. They have been identified by another specialist at the British Museum as belonging to the genus *Melanostoma*, but the species is quite uncertain.

A few specimens of *Limnophilus* were also captured on another occasion near this spot, but the species is also uncertain.

LEPIDOPTERA.

The only recorded list of Lepidoptera captured on the Falkland Archipelago was made by Dr. W. F. Dale at Darwin, but the date when the insects were caught is not stated.* During my visit to these islands I was always on the look out for insects of all descriptions; and I was able to cover a large area of ground in my rambles, I think the following list of captures made from November to March, may be considered a fairly representative one.

Soon after my arrival at Roy Cove I was delighted to notice, one fine morning, in a sheltered corner of the

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garden near the house, an attractive little Fritillary hovering over a flower. Later, I noticed numbers of the same species round the house, and also in the vast enclosures on Mr. Bertrand's property. The bright flowers growing in the sheltered corners of the garden seemed very attractive to these butterflies, and without any difficulty I captured a nice series of them. This species, *Argynnis siga*, seems to be very locally distributed over these islands. Specimens have been seen at various places on the West Falklands; and the single specimen in Dr. Dale's collection, and presumably captured near Darwin, must have been a stray specimen blown thither by the wind. This specimen is the only one recorded from the East Falklands.

Another Fritillary has been seen by several people in the West Falklands. They all described it to me as being larger and a faster flyer than *A. siga.* The markings on the wings were also more pronounced. As this butterfly has only been occasionally seen in the north-west portion of the West Falklands, it seems to be most probable that it has been wafted thither from the South American continent. The blue butterfly noticed in my previous notes appears to be quite extinct. Like Dr. Dale, I did not capture a single specimen of either Sphinges or Bombyces.

The following list has been made out for me by a gentleman in the insect department of the British Museum. The best of my specimens have been incorporated with the national collection.

Argynnis siga, Hübner.
Euxoa falklandica, Hmpsn.
Feltia capnistis, Hmpsn.
F. darwini, Hmpsn.
Pachnobia dalii, Butl.

Agrotis clerica, Butl.
Leucania falklandica, Butl.
Eupithecia auguligera, Butl.
Crambus falklandicellus, Stimpson.
Scoparia glauculalis, Stimpson.

AVES.

In addition to the published results of Bougainville's expedition already mentioned, MM. Quoy and Gaimard describe the birds collected by the staff of the ill-fated exploring vessel, "l'Uranie," which was wrecked in Berkley Sound, East Falklands. In the Zoology of the voyage of the "Beagle," Darwin described the birds captured during the visits made to the Falklands. From the years 1859-64 a number of reports on the collections of birds made either by Captains Abbott or Packe were published in the *Ibis* or the *Proceedings of the Zoological Society*, by Mr. John Gould or Dr. P. L. Sclater. Captain Abbott also published in the *Ibis* of 1860-61, two papers recording his own observations on the habits of many birds frequenting the East Island. As a natural consequence, no novelties could be expected from me after such careful observers; yet I hope the following notes taken from time to time during my two visits to this archipelago may be of interest.

The prints illustrating some of the most important statements made in this paper are from photographs taken by myself. I have placed in inverted commas the name by which each species is known locally.

I have taken as a guide Mr. Evans' recently published volume on "Birds" in the Cambridge Natural History. Those of my readers who wish for a detailed list of the birds frequenting this archipelago together with a bibliographical account of each species can refer to the above-mentioned papers by Messrs. Gould and Sclater. I wish here to record my gratitude to Dr. P. L. Sclater for kindly furnishing me with these references.

Podicipes dominicus, "Grebe." Generally distributed at least over the northern portion of the East Falklands. I have never seen this bird alive. The egg is oval in form and ivory-white in colour; the shell is very smooth. The average length of three specimens in my collection is 53 to 41 mm.

Aptenodytes pennanti, "King Penguin." At present only an occasional visitor to the Falkland Archipelago. Has never been known to nest there within living memory. A fine male specimen of this species was captured on the West Falklands during my previous visit in 1899, but I never saw it.

Spheniscus magellanicus, "Jackass." Generally distributed over the whole archipelago. Usually nests in colonies, but isolated nests are frequently met with. The nests are always made in burrows, and these vary in depth according to circumstances. If the birds are subject to much persecution, as those near Stanley are, these burrows run into the peat banks for several yards. Elsewhere, where the birds are seldom if ever disturbed, these holes are shallow. I have found this species sitting on its eggs and young in holes hardly deep enough to cover the parent bird. Once, I found two nests of this species under very singular conditions. A single tunnel extended into a peat-bank for about 2½ feet, it then branched off to the right and left for about 18 inches and then ended. In each of these diverticula was a sitting "Jackass," each with two fledglings.

When first discovered in its burrow, this species has a peculiar habit of turning its head sideways, first to the right and then to the left, as if to get a good look at its visitor, like a chameleon. I have observed that this singular habit of examining a strange object in this manner is not confined exclusively to this species. A tame bullfinch (*Pyrrhula vulgaris*) in my possession invariably examines any strange object placed in his cage in exactly the same way. A sitting "Jackass" will frequently, without any remonstrance, allow the eggs to be removed from beneath her with the crooked handle of a walking stick, if the operation is performed gently; but if violence is used, or the fledglings are present, the parent bird fights furiously, and utters the peculiar braying note repeatedly. A penguin under such conditions is not to be trifled with, a peck with its powerful bill will inflict a serious wound. Darwin (*loc. cit.*), in his notes on the Ornithology of these islands, writes concerning the habits of this species as follows: "When at sea and fishing it" (*Aptenodytes demersa*, as Darwin calls this penguin) "comes to the surface for the purpose of breathing with "such a spring, and dives again so instantaneously, that "I defy anyone at first sight to be sure that it is not a fish "leaping for sport." I have read this extract to several observing residents in the Falklands, and they all agree with me that Darwin has for the moment confused this species with the "Rockhopper" (*Eudyptes chrysocome*). I have had many good chances of closely studying the habits of the "Jackass" penguin, especially during the early summer mornings when out in my dinghy collecting in Stanley harbour; and occasionally have had numbers of them round my boat. This species invariably comes up to the surface after a dive, and appears to drink a little of the sea-water; at anyrate it moistens its bill. The bird sits very low in the water, only leaving the head and neck well exposed, the body being only slightly visible. This fact makes it almost impossible to shoot a specimen, unless a lucky shot should penetrate the brain. After an interval of a few minutes the bird again dives. I have found it most difficult to satisfy my mind how long a specimen of this species can remain under water; I believe ninety seconds is the usual time these birds remain submerged.

The eggs, which are laid early in November, are invariably two in number. They are oval in outline, and almost smooth. It is difficult to tell exactly what is the precise colour of the egg of this and the two following species, owing to the soiled condition in which one always finds them in the nests; these birds having no idea of what is politely termed "sanitary arrangements." A newly laid egg, having been gently wiped with a clean damp cloth, has a bluish tinge on the exterior, but this tint is much more pronounced on the interior. The exterior surface of the egg is chalky, and frequently bears scratches made by the nails of the parents. Dimensions of egg 72 × 55 mm. This species takes about thirty days to hatch out. The newly hatched birds are almost black, and very pretty little things.

Eudyptes chrysocome, "Rockhopper." I have already, in a general description of my trip to West Point Island, given a detailed account of the breeding places of this species. Towards the close of my visit to the Falklands, I made a visit to a very large rookery of this species placed on the southern shore of Berkley Sound. This breeding place was located on the sides of a natural amphitheatre, and measured about 200 yards across, and was about 150 feet in height. A stream of fresh water ran down the centre, roughly dividing the rookery into two parts, and falling into a large natural basin which was in communication with the sea by a passage about twenty feet wide. Here the birds could easily land during all weathers, the water in this natural basin being always smooth. The birds being fairly uniformly distributed over the sides of this amphitheatre, I tried to estimate their numbers, and after careful calculation put the total number of Penguins present from 200,000 to a quarter of a million. On climbing down to the landing place I found a huge sloping rock, very slippery, and partially covered with a species of *conferva*, beautifully scratched and marked by the constant passage of these birds to and from the sea. With some difficulty I succeeded in breaking off with a hammer and chisel some large fragments from this rock showing these markings, which I took away with me.

The nests here were made entirely of diddle-dee twigs (*Empetrum rubrum*), acres of these bushes growing on the peaty soil on the top of the cliff. These nests were, however, almost obliterated, the breeding season being quite past ; and the birds had almost finished moulting. It was interesting to see a puff of wind come over the cliff from the south-west, and drive a cloud of feathers from these birds like drifting snow. On cautiously grasping by the back of the neck several moulting birds in succession, I found I could remove the old feathers in handfuls. The date of the visit to this rookery was 14th March. In about another three weeks all these occupants would have left the place till October, when they return for breeding.

The eggs laid by these birds are two in number, oval in outline, and when clean, chalky white. They measure from 65 to 67 mm. in length, and from 48 to 52 mm. in breadth.

One of the sailors on a schooner gave me, soon after my arrival, a bird's-egg concerning which he could give me no information. I have shewn it to several old inhabitants, and they seem to be of opinion that it is the first year's egg of a Rockhopper. This singular egg is almost spherical in shape. The ground colour is dark-green, and the whole surface uniformly speckled with white spots. This single egg measures 45 mm. in length, by 40 mm. in width.

Pygosceles taeniata, "Gentoo." There is a fairly large rookery of this species of Penguin placed not far from Port William, and within easy distance of Stanley. During my residence in the Falklands, I paid several visits to this nesting-place, and was able to study these birds fairly closely. Fortunately during my first visit the day was very fine, and the atmosphere exceptionally clear; so I was able to take some very instructive photographs during their breeding season. This rookery is placed on a hill-side, and not far from its foot, and close to a stream of running water. These birds did not all nest together, but were roughly divided into three groups, and separated by a space of about fifty yards; each section containing about the same number of birds. The total number of Penguins present was about 1,200 couples. I also noticed that they were not nesting in the same place as they were three years ago, when I visited this spot; but had moved further inland along the sloping ground, the most distant group of nests being about a quarter of a mile from the shore. There was a well-marked track made through the grass by the birds, leading from the nests to the shore.

The nests, like others of the same species, are very roughly put together. A circular hole, averaging 8 inches across and about 3 inches in depth, is scraped with the feet in the peaty soil, in this are placed twigs gathered from the nearest diddle-dee bushes, which grow in abundance near the rookery. I noticed that all the twigs used in the construction of the nests had all the bark removed, and some were quite polished by being constantly passed through the birds' bills. These twigs and short branches were laid in the roughest manner in this depression, there being not the slightest attempt at architectural beauty; and after a height of 4 inches was reached, the whole was pressed down by the weight of the sitting bird; and later it was cemented together by the surrounding soil brought in from time to time adhering to their feet. When nidification has commenced, the nest resembles in miniature the crater of an extinct volcano, the rim being raised about four inches above the surrounding soil. It measures about 12 inches in diameter, and 2½ inches deep inside. I am inclined to imagine that one reason the Gentoos shift their breeding grounds occasionally is due to the surrounding soil becoming saturated with animal matter, and also perhaps to the diddle-dee bushes dying away, owing to their being constantly trampled over by the passing birds. I was particularly impressed by observing that these Penguins in one section of this rookery had quite recently settled down and made their nests in the middle of a dense growth of diddle-dee bushes. In this instance the nests were easily made. The couples having chosen a dense bush, soon trampled it down, and with the aid of a little mud, a rough but easily constructed nest was ready for occupation. As one would readily gather from reading this, the chalky-white eggs laid by this species at once become soiled, and coated with the same evil-smelling filth that surrounds the rookery. The eggs, two in number, are almost oval in outline, and when examined by transmitted light are seen to be light blue in colour, and quite smooth. They measure from 67 to 72 mm. in length, and from 58 to 62 mm. in breadth.

It was a pretty sight to observe these birds run to the sea. The well-worn paths from the three divisions into which this rookery was divided joined the main path, which, winding along the miniature valley, passed between a gap in the sandhills running parallel with the shore, and so they easily gained access to the ocean.

The Gentoos, like others of the same genus, are quite unable to fly, but run fairly fast; and although a poor athlete myself, I found no difficulty in driving them in any desired direction. Unlike the Jackass (*Spheniscus magellanicus*), these Penguins seldom propel themselves along the ground by resting on their chests and pushing themselves along by the aid of their wings and feet. This method of propulsion seems to be only employed when very hard pressed, or more frequently when an individual happens to overbalance or stumble when running away. A Gentoo always walks upright into the sea till the water is deep enough to cover him. Up to this point the bird keeps the head as high as possible, and looks as if he were walking on tip-toe; but the instant the bird gets out of his depth the head is withdrawn like a flash, and the creature vanishes. When swimming in the water it is really striking to observe the marvellous similarity between all the Penguins and the Porpoise. Indeed the resemblance is so close that many people, myself included, have frequently been deceived.

The footprints of a bird of this species on the sandy sea-shore can at once be distinguished from those of others by the curious habit it has of always trailing the third or longest digit along the surface after each footstep, and so producing a scar or mark between the footprints about three inches long.

Diomedea exulans, " Albatross." Only a visitor to this archipelago. Their nearest nesting place is South Georgia; a desolate uninhabited island about 800 miles south-east of the Falkland Archipelago. I have in my collection three eggs of this species, which were kindly given to me by the captain of a South Sea whaler, who put into Stanley on his return from those inhospitable regions. He found the nests of these birds fairly numerous along the high ground round Cumberland Bay, South Georgia. The eggs are dirty white in colour, and have a well marked zone of reddish spots at the larger end. They measure respectively 13·2 : 13·2 : 13·6 cm. by 8·0 : 8·0 : 7·9 cm. In the largest specimen the rufous spots extend almost halfway down the egg.

Ossifraga gigantea, "Nelly." Also only a visitor, being invariably driven into the numerous fiords and harbours by stress of weather. I have frequently seen two or three of these birds flying in Stanley harbour when there was a strong wind blowing. Occasionally, one bird, bolder than its companions, would rest on the water near the slaughter-house, and eagerly devour the refuse. But even then the bird would not allow one to get within fifty yards of it, so I was never able to examine one closely. I have never heard of this species nesting on these islands.

Diomedea chlororhyncha, "Mollymauk." There are not many rookeries of this species on the Falklands. I think the following list of their breeding places is perhaps a complete one:—Keppel Island, West-Point Island, New Island, and the Beauchenes. I have in my collection nine eggs laid by this species. Two came from West Point Island, and the remainder from the Beauchenes. These eggs resemble both in shape and markings those of the albatross; they are, however, considerably smaller, and the reddish spots at the larger end are much more pronounced. They measure from 11·0 to 10·4 cm. in length, by 6·4 to 6·2 cm. in width. In one of these eggs the spots at the larger end are very minute, the largest measuring 1 mm. in diameter.

Procellaria ——? I found several specimens of an unidentified species of Petrel dead on the ground on the way to the Lighthouse soon after my arrival. I was informed that quite a number of the same (?) species had been similarly found a few weeks earlier. All these birds had been killed by colliding with the single telegraph wire. They were quite dried up and so were useless for further study.

Phalacrocorax magellanicus, "Shag." There was a large rookery of this species within easy walking distance of Stanley, and as it was near one of my favourite collecting spots, I was able to visit it frequently. The nest of this species is always made of red sea-weeds and various species of hydroids; kelp, by far the easiest weed to gather, being for some reason always avoided. The nests were placed together as closely as possible on the ledges of a low cliff facing the ocean. The eggs are always of a greenish white colour when fresh and clean; and coated externally with a chalky white deposit which is frequently raised into small blisters. Three eggs are usually laid in each nest; although once I observed five eggs present. They measure from 59 to 61 mm. in length and from 38 to 39 mm. in breadth. Once I found in a nest of this species in this rookery an egg of such unusual shape that I consider it worth a separate description. This single egg was oval in outline, with the smaller end bluntly pointed. The colour externally is quite normal. It measures 68 mm. in length and 37 mm. in width.

Phalacrocorax imperialis. There is a fairly large rookery of this species on West Point Island. The nests are on a rocky hillside amid a colony of "Rockhoppers." The most striking feature about them is the pale orange red spot placed in front of the eyes. The eggs of this species are of a very pale blue colour, and not quite so chalky as those of the preceding species. My collection contains only two specimens, which measure 58 and 61 mm. in length, and 40 and 39 mm. in breadth.

Nycticorax obscurus, "Quawk." Universally distributed throughout these islands, but scarce everywhere. A very beautiful bird, but usually seen alone. During the breeding season the male has a yellow crest, composed only of three feathers, extending from the crown to the middle of the back. The first male specimen of this species decorated in this manner was observed on the 5th January in Berkley Sound; the last specimen on 15th February at Grave Cove, West Falklands. The egg of this species is quite unknown to me.

Tachyeres cinereus, "Steamer" or "Loggerhead." This is one of the commonest birds on the Falkland Archipelago, being perhaps more abundant in the numerous estuaries, than along the shores of the ocean. There is a rather curious habit always practised by the parents of this species on their young when they are old enough to take care of themselves. Both parent birds not only abandon their progeny, but drive them away. If they attempt to revisit their old homes, they are always attacked and driven away with blows by the short wings of both birds. When I was staying at Roy Cove in the West Falklands, I had excellent opportunities of studying the habits of these and other aquatic birds while walking along the sandstone cliffs skirting the little estuary. Besides this, the birds were so very tame, as they are seldom, if ever, molested; so I often went that direction.

Towards the end of January the steamer ducks were driving away their young from their homes. It was most amusing to watch the parent birds suddenly start with apparent astonishment when several of their youngsters paid them a visit. The male bird would utter his hoarse bull-frog note, and rush at the nearest intruder, who would at once turn tail, only to be overtaken and receive a very rough handling from his irate parent. Usually, however, the chase was not a successful one, owing to the furious male suddenly changing his mind while pursuing one, and rushing at a second, or a third of his fledglings; and so all would escape without chastisement. Sometimes I have observed the male bird almost startle the life out of his unsuspecting youngster by adopting the following stratagem: the parent birds would be feeding on the numerous bivalves, obtained by diving and returning to the surface to devour them at leisure; when a newly-fledged youngster would manage to approach to within twenty-five yards of them unobserved. On his being detected, the male bird would stop feeding and manœuvre round a little, as if to get the exact distance between himself and his unsuspecting visitor. All at once he would dive, and proceed under water in a bee line towards the object of his ire, when he would suddenly pop up alongside him, and instantly administer a good cuffing to his amazed youngster. Occasionally the young bird obtained a glimpse of his parent as he was rising to the surface beneath him; but usually it was too late to move, and the first intimation the young bird would receive was a 'word and a blow' delivered simultaneously. This singular method of attack is always undertaken by the male bird; I have observed it a number of times, and owing to the clearness of the sea-water have been able to watch the whole game.

The newly-fledged steamer ducks when driven off by their respective parents invariably herd together in numbers of from fifty to a thousand. At West Point Island, where this species was most numerous, I should think a thousand to be well within the limit of the numbers present. Even at times like these the birds are always fighting. They cannot remain alone, yet they must wrangle amongst themselves. One bird would in some manner offend his nearest neighbour, who at once would respond with a bite. The bird so attacked would promptly confer a like attention on the next of kin ; and so in a few moments a general engagement would take place in which perhaps fifty birds might be taking part. When all were tired out, a general truce would follow for a short time, this being quickly succeeded by another skirmish.

There still appears to be considerable difference of opinion amongst zoologists whether this species moves its wings simultaneously or alternately when moving along the water. Darwin (*loc. cit.*) writes concerning the movements of this bird as follows : . . . "but I am nearly sure that the steamer moves its wings alternately, instead of both together." I have paid great attention to the movements of this species of duck, and have made some experiments with the living birds. My opinion is that under ordinary circumstances a steamer duck when alarmed proceeds along the surface of the water by using both wings simultaneously. If the bird is suddenly alarmed, by a dog or a person appearing within arm's length, it uses both wings alternately, exerting itself to its utmost to escape. I have never observed the young birds of this species fly. According to my observations they always proceed along the surface of the water exactly like the adult birds. These observations extend from December to March.

The nest, which is usually hidden in some diddle-dee bushes not far from the water's edge, is made of grass, stems, and twigs. Seven is the largest number I have ever seen, although upwards of nine eggs have been recorded. Five eggs are usually to be found. They are laid early in November. In shape, the eggs of this species are oval in outline, smooth and glossy externally, and light cream in colour. They measure 82 to 84 mm. in length, and from 56 to 57 mm. in width.

Anas cristata, "Grey Duck." I have never seen this species alive or even examined its nest, although numbers are brought into Stanley dead by the schooners trading round the islands. They are excellent eating. A single egg of this species is in my possession. It is oval in outline, smooth, and cream coloured. It measures 66 mm. in length, and 46 mm. in breadth.

Nettion flavirostre, "Teal." Abundant in places throughout the Falkland Archipelago. These birds are also highly esteemed for table purposes. I know nothing of the nesting habits of this species, but I have three eggs in my collection. They are oval in shape, smooth, and with a slight external gloss. In colour they resemble the eggs of the duck, being light cream. They measure from 54 mm. to 57 mm. in length, and from 40 to 41 mm. in breadth.

Chloëphaga hybrida, "Kelp Goose." Universally distributed around the shores of the Falkland isles. This species never appears to go in flocks, six is the largest number I have ever seen together. They seem to pair for life.

During the nesting season, November, the snow-white gander, standing like a sentry, forms a conspicuous object along the sea-shore. I have quite satisfied my mind by observing this species feeding along the sea-shore on numberless occasions, and also by killing several and examining the contents of the gut, that these birds do not usually devour mollusks, as stated by numerous writers, but feed mainly on a common seaweed, *Porphyra vulgaris*, which flourishes between tide-marks. The nest is roughly made of grass bents, and slightly lined with feathers. Four eggs are usually deposited in it. They are of a light cream colour, oval in shape, and measure from 80 to 84 mm. in length, and from 54 to 56 mm. in breadth. They are quite smooth externally.

Chloëphaga magellanica, "Upland Goose." Abundant over the whole Falkland Archipelago. On some of the farms a reward, varying from 10s. to 15s. per hundred, is paid for the bills of this species. It is estimated that three geese devour as much grass as one sheep. In the early summer, January, the young birds make a welcome addition to one's table, and are most delicious eating. At this season the berries of the diddle-dee are ripe, and are devoured in quantities by these birds, and this food unquestionably fattens them, and adds to their delicate flavour. When a flock of "Upland geese" are disturbed, as they fly away they usually utter a note which may be rendered as "urr-urr-urr," a sound identical with that made by the Gentoo Penguin (*Pygosceles tæniata*). Indeed, the resemblance is so exact, that I defy anyone to distinguish between the species if guided by the ear alone. The nest, a clumsy affair made of grass, and with a lining of feathers, usually contains three eggs. These are laid in the early part of November. They are of a light brown cream colour, and quite smooth. They are oval in shape, and measure from 75 to 77 mm. in length, and 53 to 54 mm. in breadth.

Cygnus nigricollis, "Black-necked Swan." A striking bird, and very locally distributed. A pair of these birds were seen by an acquaintance on a pool of water near Stanley early in November; but they immediately took flight on observing him. A few still breed in places on the West Falklands. My collection contains one egg. It is fairly smooth externally, and slightly glossy. It measures 98 mm. in length, and 67 mm. in width.

Another species known as the "Black Swan" has been observed in the western portion of this archipelago at long intervals. I have not seen one myself.

Rhinogryphus aura, "Turkey-buzzard." Common throughout the whole archipelago. These birds can be easily recognised a long distance off by the tips of the primary feathers being widely separated. They are certainly the most graceful birds on these islands. Usually four or perhaps six of this species can be observed at once wheeling round high up in the sky for five minutes without once closing their wings. Usually two or more of this species could be seen near the slaughter house at the east end of Stanley, feeding on the offal. The nest I have never seen. The eggs are oval in outline, and smooth. The ground colour is ivory white, and blotched with reddish spots. One specimen only in my collection. It measures 72 mm. in length by 47 mm. in width.

Ibycter australis, "Carancho." Not very numerous. This species seems to have decreased considerably since Darwin's visit. I once found a nest on a ledge of rocks about two miles from Mount Vernet, near Berkley Sound. It contained two young birds, quite ready to fly. The parent birds were most courageous, and flew round and round my head uttering harsh cries as I climbed to the spot. Occasionally, first one bird and then the other would make a swoop at my head, and at times approach so closely that I was compelled to flourish my whip round my head lest they should actually strike me. The nest, which was placed on a deep ledge of rock about thirty feet from the ground, was very bulky, and made entirely of diddle-dee twigs and branches. It was irregularly circular in outline, and measured about three feet in diameter. The young birds crouched down, and tried to hide themselves when I approached, but they did not offer any resistance when I handled them. Both were covered with a uniform layer of dark-brown feathers; the feet were pale yellow. The eggs of this species are light cream colour, smooth, and without gloss. They are oval in shape, with dark red spots scattered uniformly over the entire surface. A single specimen in my collection measures 73 mm. by 47 mm.

Ægialitis falklandica, "Plover." This attractive bird is common on the "camp" throughout the Falklands. The nest is made entirely of a common lichen, which I believe to be *Usnea melanothrix*. It is always found in a small depression in the ground, near or perhaps under the shelter of a diddle-dee bush. Two eggs are laid early in December. They are darkish green, and covered with very dark brown spots. They are smooth and pyriform in shape. I have five specimens in my collection. They measure from 37 to 38 mm. in length and 26 to 28 mm. in breadth.

Hæmatopus leucopus, "Curlew." This and the following species were fairly numerous along the shores and fiords of the whole archipelago. The shrill piping note of these Curlews is the same as that of the familiar English oyster-catcher, *H. ostralegus*. I was never fortunate enough to find the nest of either species, although they must be fairly common. I have two eggs of this species in my collection, and although both are oval in form and measure exactly the same, viz., 60 × 42 mm., yet the colour and markings are very different. One egg is of a pale buff colour, with irregularly shaped blotches of dark brown evenly distributed over it.

The second specimen has a lighter ground colour, but the dark brown markings are of two kinds, viz., blotches and scrawls.

Hæmatopus ater, "The Black Curlew." In this species the ground colour of the eggs is warmer, approaching almost to light pink, but the markings, although of the same colour, are not so pronounced as in the preceding species. The single egg of this species in my possession measures 55 mm. by 41 mm.

Gallinago paraguaiæ, "Snipe." Very abundant round Stanley in the spring of 1898, but scarce during 1901. This species seems to be more abundant in the East than in the West island. The eggs of this species are pointed oval, smooth, and slightly glossy. The ground colour is pale olive, and the markings are brown umber scattered uniformly over the whole egg. They measure from 45 to 47 mm. in length, and from 31 to 32 mm. in width.

Megalestris antarctica, "Sea Hen." Never very numerous anywhere, but uniformly distributed throughout the whole archipelago. Two or three specimens of this species can usually be found near the slaughter-house attached to every station, and near the rookeries of "Rockhoppers" (*Eudyptes chrysocome*), but never near a "Gentoo's" rookery (*Pygosceles taeniata*). A distinctly carrion-feeding bird and very pugnacious. During the nesting-season, this species will readily attack either man or quadruped who approaches too near its nests. The eggs, two in number, are deposited during the middle of December in a nest made of grass-bents. The eggs are oval in outline, the ground colour varying considerably from grey to olive brown. The spots have a tendency in some eggs to gather at the larger end, in others these brown spots are evenly spread over the whole surface.

These eggs are large and measure from 73 to 80 mm. in length, and from 50 to 55 mm. in width. I have five eggs of this species in my collection.

Leucophaeus scoresbii, "The Dolphin." Specimens of this gull were fairly common in the neighbourhood of Stanley, Port Louis, and also at Roy Cove. None were seen after the end of February. At Stanley and Port Louis both adult and immature specimens were always to be seen during the months of November and December near the slaughter-houses in quest of offal. At Roy Cove I have frequently observed them walking on the floating beds of kelp thrown into the numerous coves after gales of wind, feeding on crustaceans attracted thither by the decaying sea weeds. I have one egg of this species in my collection. It was given to me by a very observing working man. I was unable to find out how many eggs this species lays in its nest, but my informant thought three to be the number. As with the rest of the gull tribe, the eggs are laid about Christmas time. This single egg is almost oval in outline. The ground colour is olive-brown, and the markings are dark chocolate, these blotches being uniformly scattered over the whole surface. It measures 46 mm. in length, and 35 mm. in breadth.

Larus dominicanus, "Black-backed Gull." The commonest gull in the whole archipelago and universally distributed. This species builds in rookeries and does not appear to frequent the same spot for breeding purposes two seasons running. Two or three eggs are laid in a roughly constructed nest of grass and twigs, which is usually placed on some sloping ground or on the ledge of a cliff or bank. I have eight eggs in my collection, and no two of them agree either in markings or ground coloration. The ground colour of these eggs varies from olive to buff stone colour. The brown markings, which are scattered over the egg have a decided tendency to collect as a zone at the larger end. The eggs vary in length from 60 to 65 mm. and from 40 to 43 mm. in breadth.

Larus glaucodes, "Pink-breasted Gull." This species seems to be very locally distributed. I have never seen it on any part of the Falklands I have visited. The two eggs in my collection, kindly given to me by a friend, came from the north-western corner of the East Island. They are both oval in form and irregularly spotted with dark brown, their ground colour being grey. They measure respectively 44 and 45 mm. in length, and 35 and 34 mm. in breadth.

Sterna hirundinacea, "Tern," "Split-tail." This beautiful bird is very locally distributed over the Falkland Isles. Soon after my arrival at Stanley in November, several of these birds were observed in the harbour, but about the nesting time, December, they vanished and were not seen again. Like the black-backed gull this species does not nest twice in the same place. I have two eggs of this bird in my collection. One of these is slightly more pointed than the other. They are roughly oval in shape, the ground colour is buff-coloured, and the spots of reddish brown are uniformly distributed over both eggs. Length 49 mm., breadth 66 mm.

Asio accipitrinus, "Owl." I examined a beautiful stuffed specimen of this species which was killed near Hill Cove, West Falklands, but unfortunately my notes are lost. I have never obtained the eggs of this bird.

Anthus antarcticus. I believe this to be the correct name of a pretty pipit so abundant on the "camp" of these islands. The nest is made of bents lined with fine grasses and placed on the ground. It measures 55 mm. in diameter. The eggs, which are always laid during the early part of December, are oval in outline and smooth. The ground colour is light brown, with much darker colour scattered uniformly over them. Three is the usual number in each nest. The eggs are very uniform in size and measure 25 mm. in length and 18 mm. in breadth.

Tænioptera pyrope, "Newsbird." Another species evenly distributed throughout the archipelago. I used frequently to meet with numbers of this species while collecting insects and plants along the Wickham Range of hills which run almost due east and west across the East Falklands. Its food consists chiefly of moths, which it catches on the wing with great dexterity. I have never seen the eggs of this species.

Chlorospiza melanoderma, "Falkland Island Sparrow" or "Sparrow." A little yellow bird resembling our English yellow-ammer. This is the only indigenous species that builds its nest close to human dwellings. A pair of these birds built their nest and successfully reared a family of four little ones close to my workroom in Stanley. The nest, made of the usual bents of grass, was carefully hidden away in the middle of a timber stack. The eggs are oval in outline and smooth. The ground colour is light green, with light brown spots and blotches scattered over it. These blotches have a decided tendency to congregate towards the larger rounded end. They measure 23 mm. in length, and 17 mm. in breadth. The specimens in my collection are all the same size.

Turdus falklandicus, "Thrush." Universally distributed but nowhere very abundant on these islands. The nest is roughly constructed of grass stalks and twigs of diddle-dee bushes and is usually to be found in a Fachina bush (*Chilabothrium amelloides*) or on a rocky ledge on some hill side. Mud in any form is never used to line the interior of these nests. Four eggs are usually laid in each nest. The ground colour is greenish, and covered uniformly with streaks and spots of reddish brown. I have four specimens in my collection. They measure 33, 35, 36, and 34 mm. respectively in length, by 22, 22, 23, and 22 mm.

Sturnella militaris, "Crimson breasted Starling." Locally distributed. I have never seen a single specimen of this species nearer Stanley than in Berkley Sound. This species is common at Roy Cove. I have been informed by several observing friends that this starling has been seen in most parts of this archipelago. This is one of the few birds inhabiting these islands with a brilliant plumage, and the crimson coloured breast is certainly most striking. This species does not appear to go in large flocks, twelve being the largest number I have ever observed together at once. I have in my collection five eggs laid by this species. They are oval in outline, the ground colour being white with reddish-brown spots uniformly scattered over the whole surface. They vary but little in length and diameter. The average length of these being 32 mm. and breadth 21 mm.

Scytalopus magellanicus, "Wren." I have never seen this species. Just before leaving Stanley I was shown the nest of this bird found in the neighbourhood of San Carlos. It was most beautifully constructed of wool and bents of grass interwoven in the most delicate manner, and dome-shaped. The small circular opening was placed on one side, and the eggs, four in number, were white and spotted with red. Unfortunately I did not take their measurements.

Occasional flocks of swallows, perhaps a species of either *Tachycineta* or *Procne* have been observed from time to time by the dwellers on the West Falklands and also at Darwin. Once when taking shelter behind a massive rock, near Stanley, from a passing hailstorm, towards the end of March, I certainly observed a species of Martin fly past me. This was the only occasion I ever saw one of this family on these islands.

MAMMALIA.

When I left Stanley for the West Falklands, I felt fairly confident that although I should not see a living specimen of that unique mammal the Falkland Island Wolf (*Canis antarcticus*), at least I might be able to examine some of its burrows, and perhaps be lucky enough to procure a more or less complete skeleton. Shortly after my arrival at Roy Cove, I found to my regret that this quadruped was not only extinct, but not even a trace of its burrows or skeletons could be found anywhere; so I had to content myself with collecting all the information possible concerning its habits from those who had succeeded only too well in eradicating so interesting a creature. In general the description of this species, as given by the earlier voyagers, from Dom Pernetty to Darwin, appears to have been fairly accurate. These animals seem to have been 'about' twice the size of our English fox and to resemble it in general appearance; and although very fierce looking, they were singularly inoffensive, but most inquisitive. The statement made by Darwin (*loc. cit.*) that according to Mr. Lowe . . . "all the foxes from the western island were smaller and of a redder colour than those from the Eastern, . . . " is explained by my friend Mr. William Stickney in the following manner:— "This difference in the colour of the foxes is simply due to age. The old foxes were invariably of a rusty-red colour; the young animals being always light red." These "foxes" always lived in burrows, which were never very deep, and invariably made in the side of a sand-hill. This habit of burrowing in sand-hills seems to have been for warmth and dryness; peat-banks being invariably wet. The most important fact concerning these burrows was that they communicated with each other. This is of great interest, for it points to a social habit on the part of these quadrupeds which is I believe unique. Once Mr. W. Stickney found three young cubs of this species, not many days old, comfortably coiled up, as if for mutual warmth in a partially decayed Bogbalsam (*Bolax glebaria*). His first impulse was to take them home and keep them as pets, for they were very pretty and playful; but owing to the distance to his house, and being on horseback, he was compelled to alter his decision, and so they were destroyed. Up to the time of the importation of sheep, these foxes according to Fitzroy[4] . . . "fed upon birds, rabbits, rats, mice, eggs, seals, &c., and to their habits of attacking King-Penguins, if not seals while alive, I presume that a part of their unhesitating approach to man may be traced." They were, however, never numerous, for Mr. Stickney informed me that thirty foxes is the largest number ever killed by a single person in a year. I think the main reason why these quadrupeds were never numerous was the scarcity of food. Penguins, seals, birds, and other large creatures could easily find secure shelter and rest from these freebooters, especially during the breeding season, on the numerous islands; and so they would only have . . . "rats and mice and such small deer" to fall back on; thus their means of subsistence till the advent of the sheep-farmer must have been a precarious one. It is certainly most striking how quickly these foxes changed their method of living when the farmers arrived with their sheep. Mr. Bertrand informed me that when he first settled at Roy Cove, there were many foxes about this north-western extremity of the island. Frequently during the night these animals would prowl round the house; they never barked, but gave utterance to a short "yap, yap" cry when hunting. Like the South American Puma (*Felis concolor*) this species seemed to kill sheep for sport, and considering in those days it cost £2 to land a single sheep in that remote spot, it is hardly to be wondered that the farmers waged a war of extermination.

Their method of hunting was interesting. Two or three foxes would combine forces, and rounding up a flock of sheep, dash into them and kill numbers. These sheep were invariably seized by the back of the neck, the most vulnerable spot, and one sharp bite with the formidable canine teeth would be sufficient to cause death.

Strychnine was found to be the most successful poison. A freshly killed Upland Goose (*Chloëphaga magellanica*) was thrust into a burrow after a small quantity of this deadly poison had been introduced into the system by means of a few gashes made on either side of the sternum of the bird, the strychnine being sprinkled over the cuts. This poison quickly . . . "dispersed itself through the veins. . . . ." and if the fox were at home he could seldom resist such a delicious meal, and death inevitably followed.

The last known specimen of this species was killed at Shallow Bay, West Falklands, in 1876.

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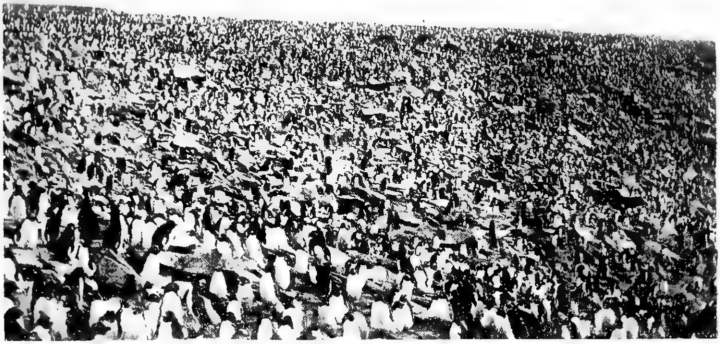

Fig. 1.

A "Rockhopper" rookery. *(Eudyptes chrysocome.)*

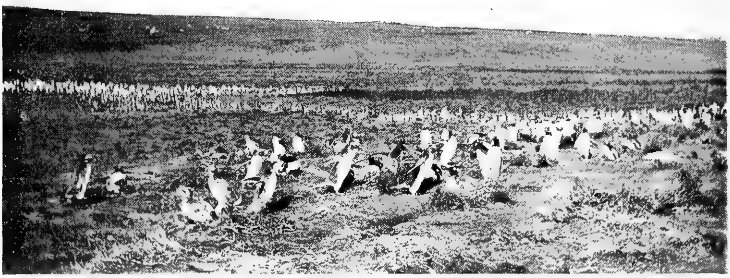

Fig. 2.

A "Gentoo" rookery. *(Pygosceles taeniata).* The birds in the distance are running to the sea shore.

Fig. 1.
Sea-weeds left bare by the tide. *Lessonia fuscescens* in the distance; *D'Urvillæa Harveyi* and *D.' utilis* in the foreground.

Fig. 2.
A bog balsam (*Bolax glebaria*) near the edge of a stone-river.

Fig. 1.

A stone-river or stream of stones. The heaped up stones on the left are artificial.

Fig. 2.

Islets of vegetation in a stone-river.

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XXIV. On the Bearing of Mendelian Principles of Heredity on current theories of the Origin of Species.

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Received and Read March 15th, 1904.

A wide field of work and speculation has been opened up to the student of evolution by Mendel: and by his followers it has been maintained that it is only by working on the lines laid down by the Abbot of Brünn that a solution of the problem of the origin of species can ultimately be reached. It is the object of this paper to show the relation which Mendel's work bears to current theories of organic evolution.

(1) *On the difference between continuous and discontinuous Variation.*

For an account of continuous variation the reader is referred to the Presidential Address to Section D of the British Association, at the Bristol Meeting, by Professor Weldon (Weldon '98): discontinuous variation is set forth by Mr. Bateson in his work "Materials for the Study of Variation" (Bateson '99); all that remains for me to do is to call attention to some of the differences between these two conceptions of variation.

Continuous variation is the name of a phenomenon of everyday observation, namely, the fact that no two individuals of a species (plant or animal) are alike; it is a permanent quality of all animals and plants at all times tending, as far as we can see, in any direction (and as little teleological in any sense of the word as anything can be imagined to be). Above all, cases of continuous variation can be described by curves of error, a fact which seems to me to have a very deep meaning. Discontinuous variation is the quality which animals and plants possess of giving rise, from time to time, to offspring bearing characters specifically different from those of their parents: in fact by some these offspring are termed 'sports.' This 'sport' is a new species: that is to say (to use Bateson's words) "Variation, in fact, *is* evolution" ('99 p. 6); but while this can be said of discontinuous, continuous variation is merely the material upon which natural selection operates (if we may thus personify that process). From this it follows that according to the latter view it is impossible to say where one species begins and the other ends; but that according to the former view there is no such difficulty.

Continuous variation may be looked upon as normal, while discontinuous may be regarded as abnormal; but this aspect of the matter is perhaps only justifiable as a help to understanding the difference. For if species have arisen by discontinuous variation it is hardly fair to call it abnormal. (*Vide* Ewart '99 p. lxxxiv.)

The word "Variation" may represent an abstract or a concrete thing: in the continuous sense it is usually a name given to the whole phenomenon of variation: in the discontinuous, the so-called sport is often spoken of as '*a* variation' (whereas a man with a cephalic index slightly less than his neighbour's would hardly be). This twofold use of the term conveniently recalls the two conceptions of variation.

(2) *Galton's theory of Heredity.*

I refer to Galton's theory of heredity because I want to show how the Mendelian theory differs from the statistical conception of that phenomenon. Galton said: "The two parents contribute between them on the average one-half, or (0·5) of the total heritage of the offspring; the four grand-parents, one quarter, or $(0{\cdot}5)^2$; the eight great-grandparents, one eighth, or $(0{\cdot}5)^3$, and so on. Thus the sum of the ancestral contributions is expressed by the series $\{(0{\cdot}5)+(0{\cdot}5)^2+(0{\cdot}5)^3$, &c.$\}$, which, being equal to 1, accounts for the whole heritage." (Galton '97 p. 402.)

(3) *Mendel's Investigations.*

Mendel, an account of whose life and a translation of whose work has been given by Bateson (**:02***a*) conducted hybridization experiments with peas in the cloister garden of the monastery at Brünn of which he was Abbot. He had found that peas differed from one another in respect of seven characters, only one of which, for the sake of simplicity, I propose to consider; that is, the colour of the seed: this was either yellow or green. When he crossed a green-seeded pea with a yellow-seeded pea, the hybrid which he obtained was always the same with regard to that character; it was always a yellow-seeded pea. Yellow-seededness therefore was called a *dominant* character; and greenness of seed a *recessive* character. When the hybrids were allowed to breed (they were self-fertilized), a curious result was obtained: 25% of the offspring were green-seeded and 75% yellow-seeded. Now it will be remembered that the hybrid was yellow-seeded; and also that that was the character of one of the parents of the hybrid; so that by mere inspection of the yellow-seededness of this 75%, we cannot tell whether they are all pure yellows, or all hybrids, or some pure yellows and some hybrids. But we can tell this by breeding from these yellow-seeded peas; for it is known that pure yellows breed true, and we have just seen that hybrids produce

25% green-seeded and 75% yellow-seeded peas. Suppose we take actually 75 yellow-seeded peas (the number, of course, does not matter, so long as it is large; but 75 is convenient as we shall shortly see), and plant some seeds from each plant. What Mendel found was this; 50 of the 75 were hybrids because 25% of their offspring were 'green' and 75% 'yellow' (which we will now write instead of 'green-seeded' and 'yellow-seeded'), while the remaining 25 proved themselves to be pure yellows by breeding true—by producing only 'yellows'. That is to say the 75 yellow peas are composed of 50 hybrids and 25 dominants; and now that we have at last found out what they are, let us look at the whole result of breeding from the hybrids. We see immediately that:—

25% greens + 75% yellows

is really represented by

25% pure greens	50% hybrid yellows	25% pure yellows
	or	
25% recessives	50% hybrids	25% dominants.

Mendel experimented with the new hybrids (*i.e.*, the children of the first hybrids) and found that they too produced offspring, 25% of which were green and 75% yellow; and he found (though he was working with small numbers: Bateson :02 p. 57) that, for at most six generations, it was a general rule that hybrids when paired together gave 25% recessives, 50% hybrids, and 25% dominants. This phenomenon is spoken of as *segregation;* which consists in the despatch by the hybrids, at each generation, of offspring into the dominant and recessive ranks from which (so long as like mates with like) there is no returning.

If we symbolise the dominant character by *D*, the recessive by *R*, and the hybrid by *DR* (and if we imagine for the sake of simplicity that each plant produces 4 seeds), we see that the proportions of *D*'s, *DR*'s, and *R*'s in successive generations are as follows :—

Generation.	*D.*	*DR.*	*R.*	Ratios. *D.*	*DR.*	*R.*
1.	1	2	1	1	2	1
	(4 + 2	↙ ↓ ↘ 4	2 + 4) =			
2.	6	4	6	3	2	3
	(24 + 4	↙ ↓ ↘ 8	4 + 24) =			
3.	28	8	28	7	2	7
	(112 + 8	↙ ↓ ↘ 16	8 + 112) =			
4.	120	16	120	15	2	15
	(480 + 16	↙ ↓ ↘ 32	16 + 480) =			
5.	496	32	496	31	2	31

The ratio of *D*'s, *DR*'s, and *R*'s can be foretold in any generation *n*, by this formula :

$$D : DR : R$$
$$2^n - 1 : 2 : 2^n - 1$$

"In the 10th generation, for instance, $2^n - 1 = 1{,}023$. There result, therefore, in each 2,048 plants which arise in this generation 1,023 with constant dominant character, 1,023 with the recessive character, and only two hybrids." (Bateson '94, p. 59).

(4) *Mendel's theory to account for his results.*

Mendel knew that green-seeded peas bred true, when self-fertilized or cross-fertilized by other green peas ; and that the same was true of the yellow. That is to say, the *germ-cells* of green peas will always produce green peas, and that those of yellow will continue to give yellow.

But what happens when a green pea is crossed with a yellow? that is, when a 'green' germ-cell meets a 'yellow' germ-cell? We know that a yellow-seeded hybrid is produced; but we want to know the condition of its germ-cells. Mendel's hypothesis was that it contained 50% 'yellow' germ-cells and 50% 'green'; no 'greenish-yellow,' and no 'yellowish-green' germ-cells, but equal numbers of green-producing and yellow-producing gametes; he maintained that no fusion of characters (like a chemical combination) takes place; but merely a mingling (like a mechanical mixture).

The proportions in which the *D*'s, *DR*'s and *R*'s occur in the offspring of hybrids is certainly accounted for by this theory. Let us (putting aside sex for brevity's sake) imagine what happens when a hybrid is cross- or self-fertilized. Imagine, first, a 'green' germ-cell: it is an even chance that it unites with a 'green' or 'yellow'

a. $G \times G$.
b. $G \times Y$.

Imagine a 'yellow': it has an even chance of uniting with a 'green' or 'yellow.'

c. $Y \times G$.
d. $Y \times Y$.

Now *b* and *c* are the same; so that the proportions in which pure 'greens', pure 'yellows' and hybrids would be produced, as the result of the random unions of the germ cells of two hybrids, would be 1 *G* : 2*GY* (hybrid) : 1 *Y*, in every four; or, of course, 25% *D* : 50% *DR* : 25% *R*. And this is exactly what happens as the result of actual breeding.

(5). *A Device for explaining Mendel's theory.*

I think this theory may be made clearer by a device which has been useful to me: some have imagined that it is intended merely as an instance of the application of the theory of probability: this, however, is not the case; its value, such as it is, lies in the way the process is managed, which has nothing to do with probability.

All that is needed is some red and white counters.

Mendel's conception of the gonad of a hybrid as an organ containing germ cells, 50% of which bear the dominant character, and 50% the recessive, can be easily imitated by a bag containing equal numbers of red and white counters: in fact the production of the hybrid (or rather its gonad) may be imitated by pouring equal numbers of red and white counters into some convenient receptacle. Now let us pair two such imitation hybrids, using for this purpose two bags or hats each containing equal numbers of red and white counters. Two vertical lines are drawn on a large sheet of paper; the space between the lines being reserved for pairs each consisting of a red and a white (*RW*); the space on one side of the two lines for two reds (*RR*), and that on the other for two whites (*WW*). A counter is taken at random out of one hat; then another out of the other hat; and the pair, according to its character (*RR*, *RW* or *WW*), is assigned to the column, on the paper, prepared for it. We should, of course, expect in a large number of trials that there would be 25% *RR*, 50% *RW* and 25% *WW*: this is in fact what happens. Now in playing this game there is only one rule, to be observed, which is "*When a red is drawn with a white the red shall be placed on the top of the white.*" (It is this rule that confers whatever usefulness there is in this device). Let us make fifty draws and place the result on the paper: the outcome of such a trial taken as I write is 13 *RR*, 26 *RW* and 11 *WW*; which, for the smallness of the number drawn, is not a bad approximation. Let that colour represent the dominant character, which was placed uppermost in the *RW*'s: let *W* be the recessive and *RW* the hybrid: the observance of the only rule of the game brings out the fact that in the hybrid it is the dominant character which is manifested, while the recessive is hidden. Now, in placing the *RW*'s on the paper one is not likely to absolutely conceal the white; so that, while from our rule, we realise that red is the character which the hybrid bears, we are prevented (by the fact that the white is not absolutely concealed) from forgetting the real constitution of the hybrids (or rather their gonads) namely that they contain germs representing respectively dominant and recessive characters in equal numbers. It will be seen from this illustration that, in making the living cross, all that is done is to mingle (if this word may be used of two objects) the germ cells together* like counters in a hat; and that, in the resultant hybrid, the germ cells differ from the two which took part in its formation, only in actual number; for the proportions are the same (50% dominant and 50% recessive) and the discontinuous condition of the germ cells is the same, in as much as a germ-cell represents *either* a dominant *or* a recessive, and never partly one and partly the other; in fact it is no more possible to produce such an intermediate stage than it is possible to get a *pink counter* by shaking up scarlet and white ones in a hat. To look for a moment at the offspring of the hybrids; Mendel says that the "extracted" dominants (the dominant offspring of the hybrids) will always breed true;

* Of course the germ cells fuse: it is the character-bearing elements which are thus mingled.

and that the same is true of the "extracted" recessives: this can be illustrated in our imitation hybridization experiment by placing half the *RR*'s in one hat and half in another; it is evident that nothing but reds can be got from "matings" from these two hats.

It is also a fundamental part of the Mendelian principle (in fact it seems to me to be its foundation-stone) that the "extracted" hybrids will produce the same kind, and proportions of the three kinds, of offspring, as the first hybrid; for if half the *RW*'s are put into one hat and half into another it is evident that random matings will give 25% *RR* 50% *RW* and 25% *WW* as before, and, what is more, that they will continue to do so (so long as we keep up the number of counters) for however long we continue the process, that is say for howsoever many generations it is carried on.

(6) *A point of difference between Galton's and Mendel's theory.*

I do not propose to discuss here the difference between the Mendelian principles and the statistical conception of inheritance, but to consider one part of the hypothesis put forward by Mendel, which is at variance with Galton's theory. I refer to the phenomenon of segregation. We have seen what Mendel says (*see* Bateson :**02**, p. 57). But this is flatly contradicted by the Galtonian generalization, according to which the greater number of generations a given hybrid is from the first hybrid (*i.e.*, of course, also from the parents of the hybrid) the fewer pure recessive and dominant forms is it likely to produce when mated with another hybrid of its own generation (Darbishire :**04**, pp. 23 et seq.).

I refer to this point (which at first sight may appear insignificant, but in reality is not) because it seems to me to afford a means of deciding between the relative validity of the two theories, inasmuch as it is a matter about which the Mendelian and Galtonian predictions are totally at variance; and because I think the time has not yet come for such statements, as, for example, this from the pen of Professor Castle (:03*a*, p. 228): "It" (Mendel's theory) "thus meets the two-fold requirement of a scientific theory, a statement of phenomena and an *explanation of them;* the "law of ancestral heredity" attempts only the first of these two things, and even here fails lamentably. It will be thus seen that the claims of Mendel's law are much greater than those of Galton's law." The italics are mine (*see* Karl Pearson, Grammar of Science, p. 121; and also in this connection Pearson :04).

(7) *New Conceptions based on Mendel's Investigations.*

I will only refer to three of these: the curious reader is referred to Bateson's "Mendel's Principles of Heredity," p. 26.

(*a*) The first of them is "the purity of the gametes in regard to certain characters" (Bateson :02, p. 26). This generalization is based on the often repeated fact, that (to take an example) in respect of the colour of the seed a germ-cell of a pea, whether it be contained by the pure yellow or pure green race, or by the hybrid or any of its descendants, *is absolutely pure.* And it is believed that it will continue to be pure in respect of these characters until a specific upheaval takes place, when a new character will arise by the process of discontinuous variation.

(*b*) The second is the conception of *unit-characters* (l.c. p. 27-28) in respect of which the gamete is pure. Such units seem to correspond to that in the adult organism which Weismann sought in the germ. These unit-characters, as we have seen, usually exist in pairs in such a way that one is dominant and the other recessive; and this fact is recognised by naming such characters allelomorphs. It is hardly necessary to say the germ contains not merely one allelomorph (as we have been imagining for the sake of simplicity) but very many: in fact Mendel recognised 7 such pairs in his peas, and this must be the merest fraction of the actual number that exists.

(*c*) We are thus indirectly led to the conception of "*compound characters*, borne by one gamete, transmitted entire as a single character so long as fertilization only occurs between like gametes." (l.c. p. 29.) The reader is here strongly advised to refer to the first thirty-five pages of Bateson's book. (Bateson :02*a*.)

(8) *The relation between these new conceptions and the theory of the origin of species by discontinuous variation.* (*a* and *b*; *gametic purity and unit-characters.*)

Let us suppose a new character to arise by discontinuous variation; for example the possession of a trunk in a race of previously snoutless elephants. According to the statistical view of heredity this new character would be soon swamped by the, so to speak, normal trunkless ancestry of the new form itself and of its mate; for one of two courses is open to the new form; it may either unite with another like it, which would depend on a series of contingencies:—the production of two such beasts at the same time, at the same place, of opposite sexes, and the condition that they were not averse to one another. Or it might unite with a trunkless relative. But even in the former case the offspring would have a smaller trunk than its two parents. And if this smaller trunk were to be perpetuated its owner would have to unite with another trunk-bearing variety which therefore would have to arise at the proper time, be of the opposite sex and in the neighbourhood; but even if the smaller trunk were lucky enough to find such an one its offspring would be less trunked even than itself! If the original trunked variety paired with a trunkless relative the swamping would be ever so much faster: but I leave the reader to pursue this argumentation for himself, suffice it to say that these trunk-bearing sports would on this view be very soon wiped out.

But if we adopt the conceptions of gametic purity and unit-characters, there is no reason, when once the variation has arisen, why it should not be perpetuated. For its germ-cells represent trunk-bearing elephants; if it mated with a similar beast its offspring would all be trunk-bearing and in the same degree; if on the other hand it met a trunkless form, the result of such a union, the hybrid in other words, would have a trunk if the possession of that organ were dominant, and would not if it were recessive; but whichever of these was the case, 25% of the next generation would be true-breeding trunk-bearers; and so on. This illustration may be crude, but I hope it shows the kind of way in which, according to these new conceptions, such a variation might be perpetuated; while according to the biometric view of heredity this would not be the case.

We have seen that a single unit-character continues to produce its like so long as it unites with its like until a new variation arises from it; but, when we come to consider (*c*) *Compound characters*, we find that new characters can arise in another way than by a discontinuous variation. I will take an example with which I am familiar. When a yellow-and-white Japanese waltzing mouse is crossed with an albino, a hybrid is produced which is unlike either parent, being, with some exceptions, hardly distinguishable from the common house-mouse (*see*

Bateson :02, note on p. 55 and pp. 24 and 25). This hybrid (I have bred some 350) is never an albino, and it never waltzes: albinism and waltzing therefore are recessive characters; and pigmentation and normal progression are the corresponding dominant characters. So that we are crossing a creature—the albino—possessing normality of progression (*D*) and albinism (*R*), with another beast which exhibits waltzing movements (*R*) and the presence of pigment (*D*). Let us consider the offspring of hybrids thus produced from the point of view of the two pairs of allelomorphs. First, with regard to colour, we should expect 25% albinos which should breed true: this is in fact what we get. Secondly, with regard to their progression, we should expect to find 25% waltzing mice: this is very roughly what happens; I have been unable to determine if they breed true (on the Mendelian hypothesis they should, of course). Now let us look at the offspring of hybrids from *both* points of view at the same time: one mouse in every four is an albino; one in every four is a waltzer, so we should expect one in every sixteen to be an *albino waltzer*. Now these albino waltzers are new things; and, what is more, they should breed true, because both their characters (*A* and *W*) are recessive. What has happened is that we have taken the recessive character—albinism—from one parent of the hybrid, and the recessive character—'waltzing'—from the other; and through the mediation of the hybrid united them in one individual—the new albino waltzer—which will produce nothing but offspring like itself, because its gametes are pure.* I have bred several examples of this new species, but have so far been unable to obtain young from them.

* I am not sure that this case is not, strictly speaking, an example of a synthetical variation; at any rate it is a very simple instance of the argument set forth in Bateson :02*a* p. 29.

The reader may suspect that there is something peculiar about these two characters—albinism and waltzing—that the former is one that is likely to have arisen as a sport, and that the latter is, in a way, pathological, and that both are of such a kind as to be very quickly eliminated in the struggle for existence: my opinion is that such a suspicion is of great interest. But I do not propose to discuss the source of such variations here: all I have tried to do is to sketch the relation which exists between Mendelian Principles and current theories of the origin of species.

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XXV. The Hymns to Tammuz in the Manchester Museum, Owens College.

By THEOPHILUS G. PINCHES, LL.D., M.R.A.S.

Read March 31st, 1903. Received in instalments between April 6th and April 20th, 1904.

These interesting compositions are inscribed on a Babylonian tablet of seemingly unbaked clay, 19 cm. (7·5 in.) high, by 15·4 cm. (6 in.) wide. The obverse, as is usual with the inscribed tablets of Babylonia and Assyria, is flat, or nearly so, whilst the reverse is convex. The text is unfortunately not by any means perfect, the lower part of the obverse being broken away, as well as the two right-hand corners, whilst the top left-hand corner is damaged, and a large piece has flaked out of the middle, rendering the first and second columns still more imperfect. The reverse has likewise lost its upper part and the lower right-hand corner, and the last column (that on the left) is still further damaged by a considerable crack, which renders the lines which it traverses practically unreadable.

The inscription which covers this document is divided into six columns—three on each side, and there are two lines of writing on the left-hand edge. The number of lines in each column, as the tablet is at present, varies from 31 in Col. III. (the right-hand column of the obverse), to 43 in the last column (the left-hand column of the reverse), the total number of lines, including the two on the edge, being about 216 in all. It will therefore be seen, that the text is one of considerable length.

The style of the writing is archaic Babylonian, closely resembling that in use at the time of the dynasty of Babylon, to which the well-known and renowned king

Ḫammurabi (the Amraphel of the fourteenth chapter of Genesis) belonged, and the date when the text was written may therefore be set down as being about 2,000 B.C. On the whole, the characters are well formed, but some of them are written not quite fully, whilst others have peculiarities which certain of the Babylonian scribes of the period affected. It cannot be said, however, that the writing is bad—indeed, it may be taken as a good average hand, rather above the mean in the matter of excellence. As is usual in texts of this period, lines are ruled across the columns—some deep, the majority shallow. The latter are those against which the scribe ranged his characters, the thick tops of the wedges, not the bottoms (which are mere points), touching. The *deep* ruled lines are those which divide the paragraphs or sections.

In an inscription of this kind—that is, a Sumero-Akkadian text, unprovided with a Semitic Babylonian translation—it is necessary, at the outset, to say something in justification of the title, namely, the statement which I have made, that it is a composition referring to Tammuz. This is due to the fact that his name occurs several times in the inscription. It is to be found in Col. I., lines 8, 13, and 17; Col. III., lines 8, 13, and 15. As is well known, Tammuz was the husband of Ištar, and her name occurs likewise, as was to be expected (Col. I., lines 27, 28, 29, 32; Col. II., lines 1, 4, 8; Col. III., lines 13, 15; Col. IV., line 24; Col. V., line 6; Col. VI., lines 7, 9, 11, 23), under its Sumerian form, namely, Innanna, a name by which she was known in Babylonia until an exceedingly late date. In this connection it is noteworthy that the word for husband, *mutna*, apparently referring to Tammuz, Ištar's spouse, is not unfrequent.

The two chief personages, and their relationship, being therefore well established, a reference to such non-

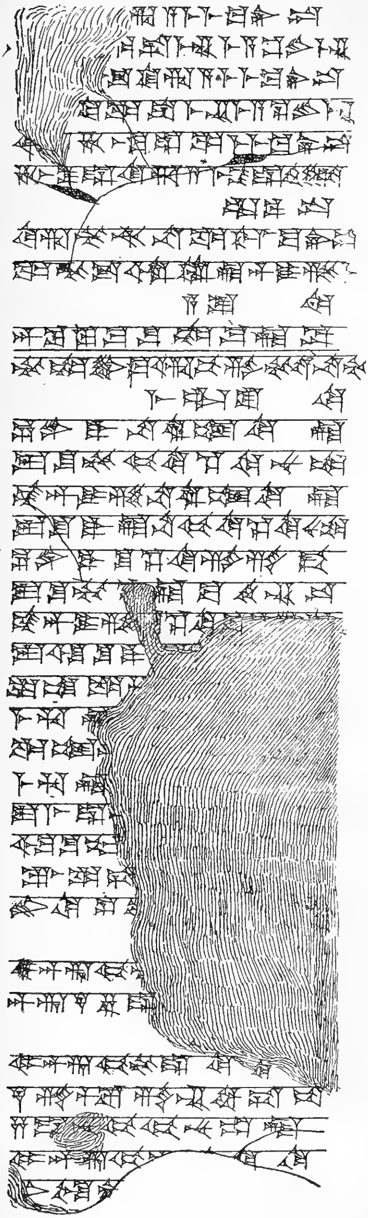
Semitic words as are certain will suffice to show that the nature of the text, apart from the personages, is in accordance with the title. These, which, by their occurrence, may be called the 'key-words,' number about 60, and show that, whatever may be the *unavoidable* defects of the rendering which I have made, the nature of the inscription has been correctly ascertained, as far as is possible with our present knowledge. This, when one considers that the Sumerian language has been practically dead for about three thousand years, and was wholly lost to view and forgotten for from half to two-thirds of that time, may be regarded as thoroughly satisfactory. Moreover, whatever defects my translation may contain are in all probability mainly due to the exceedingly difficult nature of the language and the defective nature of the script in which it is written. In addition to this, it may be noted, that the meanings of the words are only attainable through the medium of Semitic Babylonian, and that the Babylonians themselves, in their translations, are not seldom in doubt as to the way in which the words and phrases ought to be rendered, two, and even three possible renderings being sometimes suggested in the documents which have come down to us. In addition to this, the present inscription is written in a variation of that form of Sumerian which is known as 'the dialect,' and instead of using ideographs, as in the case of most other Sumerian inscriptions, the words are, in this inscription, generally spelled out. This is naturally very important and interesting, but it does not help the modern translator, partly on account of the large number of homophones which Sumerian contains, but principally because we do not know, in many cases, the pronunciations of the characters when used ideographically. When, therefore, a text is written ideographically, we translate without being certain as to the transcription, which, in such a case, becomes a secondary matter. The translator of such an inscription as the present, however, is thereby deprived of the material for comparison, namely, the word spelled out in full—a most important element.

Having thus shown that the translation which I here give, though it may not be in every particular *the* rendering, is at least a possible rendering, as far as my available material goes, I give a selection of such words or roots contained in the text as may be regarded as certain.

abba, old man, elder.
am, lord, hero.
ama, mother.
ašaba, field.
azaga, bright, pure, glorious.
a-zida, right hand.
babar, to shine brightly.
balagi, lamentation.
banda, powerful.
bi, that.
du, to come, go, bring.
ê, house.
ê, to speak.
el, to be pure.
ellu, hurrah!
erim, enemy.
gala, great.
gigi (*giga*), to return, bring back.
gu, to speak, cry out.
ġia, let him, (her, it) be.
i, to praise, glorify.
idib, voice.
igi, eye, to see.
ila, to raise, to be high.
ki, place.
kinene, censer (burnt offering).
kur, country, land.
lu, man, he who.
lum, to grow.
magala, greatly.
mara, to make.
me, voice, word, etc.
men, I am, thou art.
mi, night, dark, black.
mu, name, poss. pronoun, my.
mugib, goddess, Ištar, votary of Ištar.
nin, lady.
nu, not.
pada, to announce, invoke.
ra, to.
šab, heart, middle.
sala, woman, to be broad.
šara, to cry out.
še, seed, grain; to hear.
ši, life.
si-sa, to direct.
šu, hand, benefit.
šu-mala, to bow down.
ta, in, from, to, for.
tia, to receive.
tila, to live.

Column I.

Text.



Transcription.

1\. . . . . . . ri-a me-me-ma ni-du

2\. . . . [di-k]a-ša-me-en me-a-si, dinig

3\. . . . . da ki-ri-a me-me-ma ni-du

4\. . . . di-ka-ša-me-en me-a-si, dinig

5\. ki[-ri ?] ḫa-aš ma-ra-ka me-me-ma ni-du

6\. ḫa-aš ma-ra ki-ri-a me am-ra ḫi-li
al-ma-du

7\. di-ri mu-ti-na gu sal-la-ba ni-du

8\. gu-mu-da-pad el-la (dimmer) Ṭumu-zi-me
a - su - di

9\. an-zu dib-ba šu-ne-ma-la dim

10\. mu-ne-in-ma-ar-bi gi mu-ut-na-mu
me al - su - di

11\. e lu gala na-ru ag-di-la

12\. ama šu-mu ul silim si-sa nu-pil

13\. am (dimmer) Ṭumu-zi na-ru ag-di-la

14\. ama šu gal-la-na ul silim si-sa nu-pil

15\. e lu gala šu si ki gi-gi-ga

16\. ama šu-mu gal(?)-la ba ḫi-en-du

17\. am (dimmer) Ṭumu-zi . . si-sa ba . .

18\. ama û šu gala . . . .

19\. gu ag-gu . . . .

20\. me ḫu-la . . . .

21\. gu ag-[gu] . . . .

22\. me ḫu-la . . . .

23\. ama me-ra . . . .

24\. û šu ur . . . .

25\. ama me ka-ta . . . .

26\. lu silim si- . . . .

27\. mi (dimmer) Innanna ul-m[u-ra di-di]

28\. (dimmer) Innanna, ig-azaga-ra . . . .

29\. mi (dimmer) Innanna ul-mu-ra di-di

30\. ig-gi bara-zu gi-en im-ta-ta

31\. za-ra nu-du-du nu-um-la

32\. mi (dimmer) Innanna ul-m[u-ra] di-di

33\. . . nina-mu(?) . . . .

Five of the above lines are double, so that, reckoning them all, long and short alike, including the blank spaces after lines 26 and 28, the total number in the column originally amounted to 38.

tu, to enter.
ṭumu, son.
tur, small, to be small, young.
ù, and.
ua, food and drink, provider of do.
umun, lord.
ušu-gala, unique and great.
za, thy.
zara, barrier.
zida, firm, fixed, lasting.
zu, to know.

and in all probability other examples could be added to the above.

Though this inscription, in comparison with the numerous others, which are published, does not contain many of the verbal prefixes, suffixes, and infixes, which are a characteristic of both dialects of Sumerian, there are nevertheless a few such particles, which, though their meanings are fairly certain, have not been included in the above list. These will be found in the "Notes upon the Words" at the end.

I now give my provisional translation of the first five columns, with part of the sixth, trusting that it will be found not without interest, in spite of its present mutilated and rugged condition :—

COLUMN I.

Ištar, or one of her devotees, calls for Tammuz.

1. . . . . . into the [place] of pasture, calling, she goeth :
2. . . . . . 'Thou art taken. Where is he, the prince?'
3. . . . . . into the place of pasture, calling, she goeth :
4. . . . . . 'Thou art taken. Where is he, the prince.'
5. For (?) the command to disappear (?) calling, she cometh.
6. Making to disappear—into the place of pasture the voice to the lord * in joy comes forth.
7. For (my) husband the command in fulness comes—
8. The clear summons of Tammuz resounds afar off—
9. She who knows takes and subjugates him.
10. The call, 'Return, my husband,' resounds afar off.
11. Saith he who is great, the singer, who recordeth :

* *i.e.*, the god Tammuz.

12. 'Mother, my release (in) joy (and) peace direct, rest not.'
13. Lord Tammuz, the singer, who recordeth—
14. The mother directeth his great release, (in) joy (and) peace not resting.
15. Saith he who is great, with full hand to his place returning: *
16. 'Mother, grant my great (?) release, let it come.'
17. Lord Tammuz, directing (and) granting (thy) [release, she returneth].
18. The mother and the great release . . . . .
19. The cry of the caller (?) . . . .
20. The evil voice . . . .
21. The cry of [the call]er . . . .
22. The evil voice . . . .
23. 'Mother, to the voice . . . .
24. And the release . . . .
25. Mother, the voice from the mouth . . . . .
26. A man of peace, directing (?) † . . . .
27. Night Ištar en[closing, she advanceth].
28. Ištar, to what is pure . . . .
29. Night Ištar enclosing, she advanceth . . . .
30. 'Right remains by thy side, it stands firm.'
31. The barrier unbroken she seeth not.
32. Night Ištar enclosing, she advanceth,
33. . . my sister (?) . . . .

The 'place of pasture' *ki ria*, is in all probability the domain of delight where Tammuz, the shepherd (*rê'u* in Semitic Babylonian) dwelt with Ištar, his spouse. Here the summons of Ereš-ê-gala in the Underworld seems to penetrate, and is heard by Ištar with sorrow and misgiving. It is a joyful sound, however, in the mouth of her who calls.

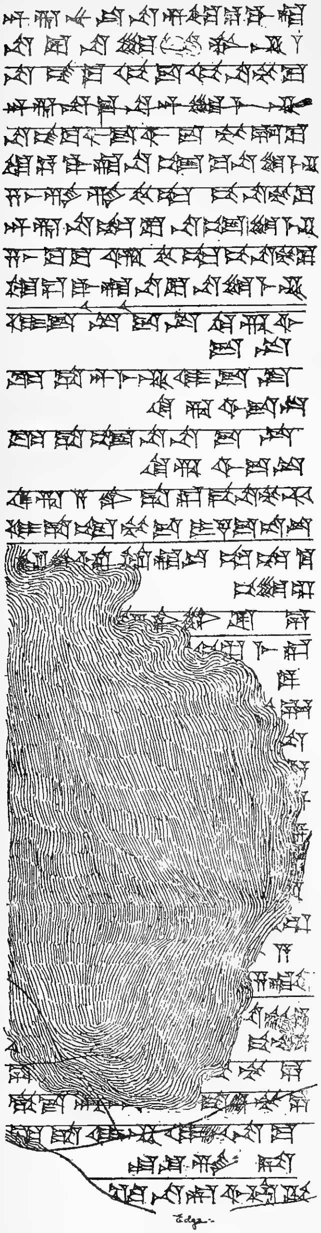
After line 9, there is apparently a division in the

* Or, by reading *sa* (*di*) for *ki*, and thus getting the word *si-sa*, as in line 12: "Saith he who is great: 'Direct (my) release, return (to me).'" *Sa* (*di*) has one horizontal wedge less than *ki*.

† Or "He who peace di[recteth] . . . . . ."

Column II.

Text. | *Transcription.*



1. (dimmer) Innanna nu-gin-na (dimmer) Ereš-e-gal-la
2. na - zu na - tu - me* - en*
3. Na - am-zu ru-da ul-na-mu-zu
4. (dimmer) Innanna na-zu na-an-tu-me - en
5. Na-am-zu igi-da igi-da mu-un-zu
6. ereš-e-gal-la na-am-zu na-tu-me-en
7. Za-rum gi-gi ku-ur†-bi na-mu-zu
8. (dimmer) Innanna na-ne-zu na-am-tu-me-en
9. Za-rum ba-ba-ar ku-ur†-bi na-mu-zu
10. ereš-e-gal-la na-zu na-tu-me-en

‡

11. Mi da-du da-du di-ri-ši da - du
12. Ka-ša-an-me-en mi da - du di - ri - ši da-du
13. Ka-ša-am-na-na da - du di§-ri - ši da-du
14. Ki-ri-a lu ša-ga ga-na mu-u
15. mi-ša-am mu-da i-gar da-ab-du

16. El lu pad-el-la du-ur-ne-ku bi-tu-um
17. [El lu pad-e]l ni-in - su - e
18. . . . . ku-ur† me-ga
19. . . . . ma
20. . . . . -un
21. . . . . -na
22. . . . . -a
23. . . . .
24. . . . .
25. . . . .
26. . . . .
27. . . . . -um
28. . . . . -a
29. . . . . za-la-di
30. . . . . na mu-e
31. . . . . ga mu-e
32. ta(?) . . . . ga mu-e
33. ga-da-an . . . . ša a mu-e
34. Ka-ša-me-en mi sumun-na-ma šu-šu - gi - ta

35. . . . . ka-na-ga ši pad-gala

* Written over other characters.

† Written *kur-ur*, the latter being the "phonetic complement."

‡ Two "corner-wedges," like the character *u* twice, cross this line beneath *gal* and *la*.

§ Written as *ki*, with three horizontal wedges.

text, implying a change in the subject; and, in fact, 'the voice afar off' now seems to be that of Ištar, calling *Gi, mutna-mu*, 'Return, my husband.' He, too, would like nothing better, and asks her to direct, to arrange his release, not resting until it is accomplished. The word which I have translated 'release' is *šu*, meaning 'hand,' and, secondarily, 'preservation.' To all appearance this meaning arises from the idea of the hand as 'the helper,' and is an interesting example of the evolution of the signification of a word in Sumerian. In the mutilated part which follows, there would seem to be a conflict with the voice of Ištar, and some 'evil voice' which called Tammuz away, but upon this point there is anything but certainty. At the end of the column the goddess seems to be represented as on the journey to the underworld, travelling in darkness, and not seeing the unbroken barrier before her, preventing her advance.

Column II.

Ištar enters the Domain of Ereš-ê-gala, the 'Lady of the Great House.'

1. Ištar obeyeth not Ereš-ê-galla:
2. 'She who knoweth, she who entereth, am I.
3. She knoweth not (my) breaking through—let her not know it—
4. Ištar, she who knoweth, she who entereth, am I.
5. She knoweth not—seeing, seeing, I know it—
6. Ereš-ê-galla knoweth not that I enter.
7. A barrier hindereth, but this land I know—
8. Ištar, she who knoweth it, she who entereth, am I.
9. The barrier is high, but this land I know—
10. Ereš-ê-galla, she who knoweth, she who entereth, am I.'

---

11. In night surrounded, surrounded, in gloom surrounded,
12. Lost am I, in night surrounded, in gloom surrounded,
13. Lost is he, surrounded, in gloom surrounded.

14. To the place of pasture, fair one, come, husband.
15. Midnight dark (as) an enclosure surroundeth thee.

---

16. Pure one, who hath the pure invocation,* enter the abode of rest.
17. [The pure one, who hath the pu]re [invocation],* maketh to increase.

[*Sixteen defective lines interrupt the sense here.*]

34. Lost art thou, darkness-afflicted, as in old age.

---

35. . . . . . . the bolt, life announcing.

The name of Ereš-ê-gala is naturally one of the most important key-words of this column. It has the determinative prefix of divinity in the first line only, but whether this has any significance—such as, that the goddess was not held in any great respect by the votaries of Ištar—is uncertain. The barrier which was set between this world and that below seems to be referred to by the legend of the hero Gilgameš purchased by Dr. Meissner for the Museum of Berlin, and published by him in the *Mittheilungen der Vorderasiatischen Gesellschaft.*† The word required is *zara*, and it would seem exceedingly probable that the *zarum* of this text is the same, slightly modified by Semitic influence, whereby *a* has been changed to *u*, and the mimmation (probably unpronounced) added. The true rendering of the words *namzu*, *ulnamuzu*, *nazu*, *munzu*, *namuzu*, and *nanezu*, presents considerable difficulty, but I have thought it best to regard all those with *m* after *na* as negative forms, as in the standard dialects, and the sense seems to come out fairly well. The gap after line 18 is a very unfortunate one, as the lost portion might have rendered considerable help in translating that which has been preserved.

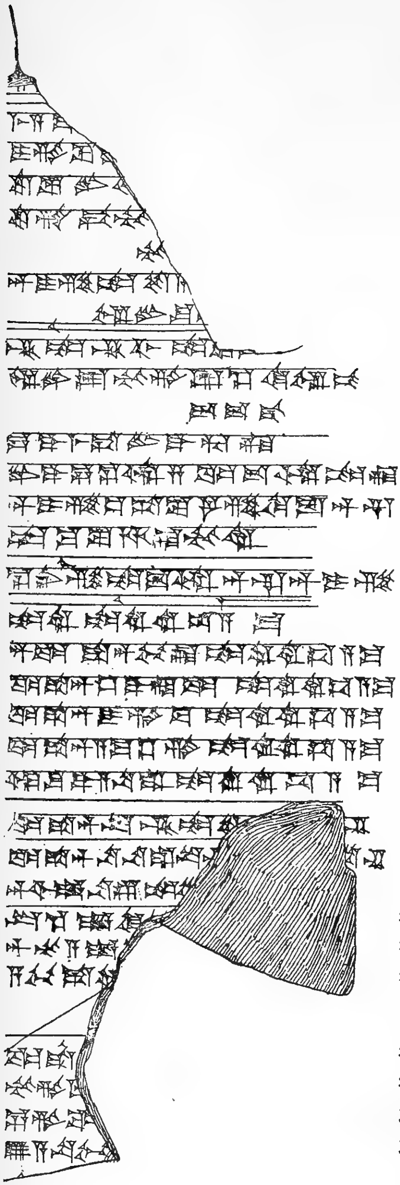
* Lit. "Man of the pure invocation."

† Translated also by the present writer in the *Proceedings* of the Society of Biblical Archæology, March and April, 1903.

Column III.

Text. *Transcription.*

About three lines are wanting at the beginning.



. . .

4. Me-a ma . . . .
5. I-gi-zu . . . .
6. Šaba-zu lu . . . .
7. Šaba gi-ga mu- . . . .
   mu- . . . .
8. (dimmer) Ṭumu-zi ne-te-a . . . .
   el lu šu . . . . *

9. En-ne-en-igi ne-zu (?) . . . .
10. El lu ama mu-gi-ib nigin ki el am da-da-ga
11. E-gala me-ta lu gala ḫu-la
12. Lu gala e-si pada za-du-da pada pil-la
13. (dimmer) Ṭumu-zi giš-ta-zu ig-zi-di-iš (dimmer) Innanna
14. Ur-ma-zu ḫa-la mu-ru †

15. Si-ir nam-ne-da-pada (dimmer) Innanna (dimmer) Ṭumu-z ‡

16. Erim erim ru-uš-a - ma
17. Dimmer ka-ša dimmer gu-la erim ru-uš-a-ma
18. Ka-ša dimmer giš-gal-la-ka erim ru-uš-a-ma
19. Ka-ša (dimmer) Ṭumu-gi-ba erim ru-uš-a-ma
20. Ka-ša (dimmer) Ama-elaga-gi erim ru-uš-a-ma
21. U-šu-gal-a-na-ra erim ru-uš-a-ma

22. Ka-ša an-du en-ne-te[-en en-ne-te]-en
23. Ka-ša dimmer Na-na-ra du e[n-ne-te-en en-ne-t]e-en
24. dimmer Ši-umun-na-gi ne-te . . . .
25. Du-si Unug ki . . . .
26. dimmer mu-a Unug ki . . . .
27. A-gu ša ki ? . . . .
   . . . .

28. Ka-ša . . . .
29. Mu-gi-ib . . . .
30. E-gi ka . . . .
31. u-a na-gu . . . .

One or two lines are wanting to complete the column.

* A small "corner-wedge," like that for *u*, is written between the two ruled lines on the tablet.

† The character *kur* or *pap* is written above the word *si-ir*.

‡ A "corner-wedge" is written above *erim*, and an upright above *a*.

Ereš-ê-gala, 'the Lady of the Great House,' is apparently another name of the goddess Allat (Persephone) who, as Queen of the Underworld, is generally called Ereš-ki-gala, 'the Lady of the Great Region,' and both names are evidently synonymous.

COLUMN III.

Praises of Tammuz, and exhortations to save himself from the enemy.

3. . . . .

---

4. To us . . . .
5. Thine eye . . . .
6. Thine heart, man . . . .
7. The evil heart hath . . . . . . hath . . . .
8. Tammuz approacheth . . . . . pure is he who . . . .

---

9. He hath seen it, he knoweth . . . .
10. Pure is the man, (his) mother is goddess of all, to the glorious place of the lord may he arise;*
11. The great house rejoiceth at the voice of him who is great.
12. He who is great and powerful calleth, in darkness invoking light.
13. Tammuz, thy domain is the delight of Ištar.
14. Thy limbs are active and strong.

---

15. Beautiful is the chant of Ištar and Tammuz.

---

16. The enemy, the enemy rageth.
17. Lost god, great god, the enemy rageth.
18. Lost one, god of the domain,† the enemy rageth.
19. Lost one, Ṭumu-giba,‡ the enemy rageth.

* Or, "Glorious is he (whose) mother is goddess of all—to the glorious place may the lord (*i.e.*, Tammuz) arise."

† Lit., "the place," probably meaning the earth.

‡ "Son of the flute." This instrument was played when Tammuz came forth from the underworld, as we learn from the "Descent of Ištar into Hades."

20. Lost one, Ama-elaggi,* the enemy rageth.
21. Against her peerless one the enemy rageth.

---

22. The lost one comes, he is at pe[ace, he is at pe]ace.
23. The lost one comes to Nana, h[e is at peace, he is at p]eace.
24. Ši-umunnagi † is [at peace, at peace].
25. Exalted in Erech ‡ . . . .
26. Divine name (in) Erech . . . .
27. The crown . . . .

---

28. Lost one . . . .
29. The goddess . . . .
30. Prince. . . . .
31. Nourisher of . . . .
32. . . . .

In this column there is but little of interest except the names, and the various stanzas seem to be somewhat disconnected. The first of them is exceedingly imperfect, but it would appear, with the second, to recite praises of Tammuz, who is apparently conceived as coming forth from the Underworld, and the pleasure of Ištar in his domain and in his person are referred to. But the voice of joy suddenly turns to that of apprehension, when the thought occurs that the god will have to return to the sombre domain, which he has just left, before the year had run its course.

COLUMN IV.

The goddess thinks of the glory of Tammuz, and laments his loss.

1. Going . . . .
2. A crown in the midst . . . .

---

3. He illuminateth; he illuminateth.

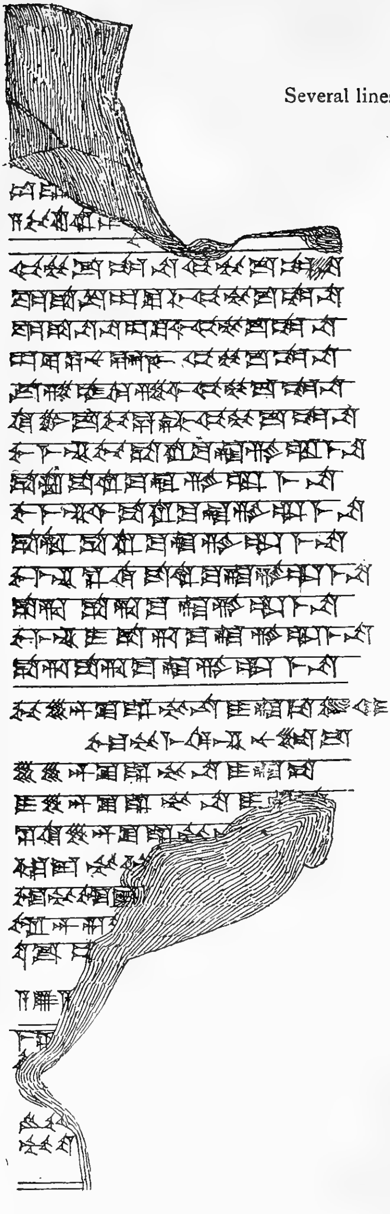
* Perhaps "Honoured mother." Another name of Tammuz means "Peerless mother of heaven." Possibly he was a hermaphroditus. Or is Ištar, his spouse, referred to?

† "Life of the people." This is apparently a parallel to the non-dialectic Zi-ukkina (with the same meaning), a title of Merodach, who may be intended here. In this case the rendering would be "*he* is at peace."

‡ Ištar was worshipped in Erech, which was one of the chief centres of her cult.

Column IV.

Text. *Transcription.*



Several lines are lost at the beginning.

1. Du ra . . . .
2. A-gu šaba ru bar(?) . . . . *

3. Ul-mu-da-ne-na ul-mu-da-ne-na
4. Ka-ša du ab-zu igi ul-mu-da-ne-na
5. Ka-ša na-na ab-zu igi ul-mu-da-ne-na
6. Ab-zu e-nu-un igi ul-mu-da-ne-na
7. A-zi ib-di zi igi ul-mu-da-ne-na
8. Ki in-da-gu e-ni igi ul-mu-da-ne-na
9. Sala-me-en gu ša-ru ba-la-gi al-me-na
10. Ša-ri † ša-ru ba-la-gi al-me-na
11. Sala-me-en ši ša-ru ba-la-gi al-me-na
12. Ša-ri † ša-ru ba-la-gi al-me-na
13. Sala-me-en si-sa ša-ru ba-la-gi al-me-na
14. Ša-ri ša-ri ba-la-gi al-me-na
15. Sala-me-en i ša-ri ba-la-gi al-me-na
16. Ša-ri ša-ri ba-la-gi al-me-na

17. Gu še an-su-ra mu-na i-la-ta lum-mi
18. mim-ma-mu me-de-en nu-li-iš
19. Še še an-su-ra mu-na i-la-ta
20. I še an-su-ra mu-na i-la-ta
21. Si-sa še an-su-ra mu-n[a i-la-ta]
22. Û ama mu-pa[da]. . . . . . .
23. Nin-mu nin ama. . . . .
24. El (dimmer) Innanna. . . . .
25. Ud-da ne(?) . . . .

26. A-u a-[saba]. . . . .

27. Me-zu (?). . . . .
28. . . . .
29. Šiš . . . .
30. Mu-ut- . . . .

The last two lines are written on the edge or thickness of the tablet.

* A "corner-wedge" is written below this line just after *bar*.

† Apparently *ru* was written first, and then corrected to *ri*.

4. The lost one, wandering in the Abyss, illuminateth the region;
5. The lost one, resting in the Abyss, illuminateth the region;
6. The Abyss, the great water, he illuminateth the region;
7. On the right he advanceth, dawning, he illuminateth the region;
8. Where he dwelleth, the lord, he illuminateth the region.
9. The woman am I, uttering the cry of lamentation, releasing—
10. The cry, the cry of lamentation, releasing.
11. The woman am I hearing the cry of lamentation, releasing—
12. The cry, the cry of lamentation, releasing.
13. The woman am I directing the cry of lamentation, releasing—
14. The cry, the cry of lamentation, releasing.
15. The woman am I honouring the cry of lamentation, releasing—
16. The cry, the cry of lamentation, releasing.

---

17. Uttering, the grain breaketh forth, growing after it cometh out—
18. my reward send thou in plenty.
19. Hearing, the grain breaketh forth, growing after it cometh out.
20. Honouring, the grain breaketh forth, growing after it cometh out.
21. Directing, the grain breaketh forth, growing after it cometh out.
22. And my mother invoketh . . . .
23. My sister, the sister of the mother . . . . .
24. Pure is Ištar . . . .
25. When . . . .

---

26. Ah, [he returns to] the fi[eld, he returns to the field].

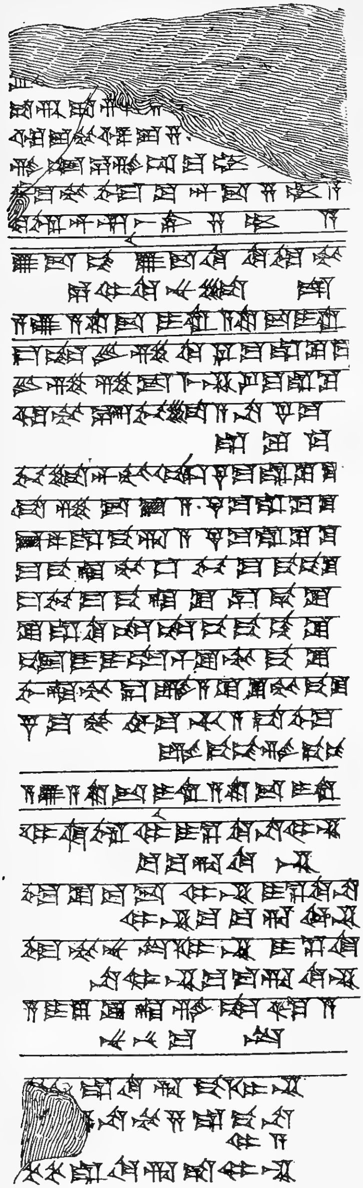
---

27. Thy (?) voice . . . .
28. . . . .
29. The brother . . . .
30. Husb[and] . . . .

This column contains a number of unusual words, and is, on that account, exceedingly difficult to render with the material which we possess at present. How far my rendering represents the true sense of the original is doubtful, but thus much may be claimed for it, namely, that *abzu* is the usual Sumerian expression for the Abyss, the abode of the god Êa or Aê, where, according to the lists of gods, Tammuz dwelt, and though this does not seem to have been the infernal regions in the true sense of the word, it possibly bordered on them, and may have communicated with them. In this Abyss, which was rather one of the abodes of the blessed than the other place, was the *a-nunna*, or 'great water,' apparently the depths of the ocean, whence came, according to Berosus, the beings—including Êa (Oannes)—who taught the Babylonians all they knew. As the Sumerian word for 'water,' *a*, is sometimes weakened to *e*, I have regarded this word as existing in the expression *e-nun*, which has all the more appropriateness, as this is a dialectic text. The repetition of certain words will show the reader how the sense is arrived at, and it is only necessary to say, that the roots *gu*, *ši*, for *še*, *si-sa*, and *i*, which I have rendered, following the bilingual lists, by the words 'uttering,' 'hearing,' 'directing,' and 'honouring,' respectively, are repeated in the part referring to the growing of seed, where they occur, however, with the last two elements interchanged, the order being *gu*, *še*, *i*, and *si-sa*. As god of the summer sun, Tammuz was naturally the divinity who caused things to grow, hence the lines inserted here, which show how the Babylonians regarded themselves as being indebted to him for the necessaries of life which they enjoyed. Seemingly the lamentations which released Tammuz from the Underworld caused, by that act, the seeds which had been sowed to germinate.

COLUMN V.

Text.



Transcription.

Several lines are lost at the beginning, but not so many as in the case of Col. IV.

1. Ru(?) . . . .
2. Ša-ri ša-ri . . . .
3. Û ama-mu û ama-za . . . .
4. Gi ag-e-gi ab-ba ḫi - [a]
5. [Mi]mma-mu mimma ba-an-da-za ḫi-a
6. Ki el (dimmer) Innanna aš-ni-za ḫi-a *

---

7. U-da am u-da di-di mimma-mu
8. e-mi-di nu - li - iš
9. A-u a-šaba-da i-ru a-šaba-da i-ru

---

10. Giš-izi lu zi di ig-ma-ra-zu-ku
11. Lu zi zi-da-me-en ig-ma-ra-zu-(ku)
12. Û-mu-un gu-li a-na ig-ma- ra-zu-ku
13. Gu-li dimmer Mu-til(?) ig-ma-ra-zu-ku
14. A-zi-da ê(?)-a ig - ma - ra-zu-ku
15. Ê pa-ra ga-ri-a ig-ma-ra-zu-ku
16. Ma-ga-la-mu giš-gu ma ga-am-su
17. Giš-gu ma-ga-la su ê ga-su
18. Su-ra ki-ne-ne-bi ga-am-su
19. Aga-tur-tur-ur† maš-su-mu ga-su
20. Sal-la-mu Ê-gi-a su-su-mu ga-su
21. Ig-ba-mu im-ma-ti-a-ta mimma gi-ga-am gi-ga-am

---

22. A-u a-šaba-da i-ru a-šaba-da i-ru

---‡

23. Mi ki el mi i-si-di-na-me-en ba-ba-ri-di-en
24. Mimma su-ba-da-mi-en i-si-di-na-mi-en ba-ba-ri-di-en
25. Mimma-mu nu-du-mi-en i-si-ki§-na-mi-en ba-ba-ri-di-en
26. A i-dib su-la-gi-ne û-a nu - nu ma - du

---

27. [Kur-kur]-ra di-ri - ša - me-en
28. [Mu-u]t-na-mu za - ra ga - na mi - a
29. Kur-kur-ra di-ri-ša - mi - en

* A "corner-wedge" crosses this line just below and after Innanna.

† Read *aga-turtur* simply—the character *ur* is apparently a phonetic complement.

‡ There is a "corner-wedge" below this line under the *i* of the first *i-ru*.

§ For *di* or *sa*.

Column V.

Prayers and Praises to Tammuz.

1. . . . .
2. The cry, the cry . . . .
3. And my mother and thy mother . . .
4. The sceptre of dominion, elder, let it be.
5. My recompense the recompense of thy (youthful) glory let it be.
6. The glorious place (O) Ištar, thy gift(?) let it be.

---

7. *U-da am, u-da didi*, as my recompense
8. send thou in plenty.
9. Ah, he returns to the field, he returns to the field.*

---

10. The torch,† faithful (and) perfect man, (is) in thy dwelling;
11. Faithful one, everlasting art thou in thy dwelling;
12. Great lord, whatever (there is is) in thy dwelling;
13. Great is the goddess Mu-til(?) ‡ in thy dwelling;
14. (At) the right of the house(?) in thy dwelling,
15. Let a shrine be founded in thy dwelling.
16. My "Greatly" let me then speak—may it increase.
17. Let me say: "Greatly increasing may the house increase;
18. May the sacrificer increase his incense-offering;
19. May my supreme one increase what is very small;§
20. My fullness is in Ê-gia, let my growth increase.
21. After he has received my offering, the reward return, return (to me)."

---

22. Ah, he returns to the field, he returns to the field.*

---

23. Dark is the place of purification, the night thou hast made brilliant—thou hast made bright.
24. The recompense hast thou made glorious, brilliant, and bright,
25. My recompense hast thou not withheld—thou hast made it brilliant, thou hast made it bright.

* Or, possibly, "Ah, the field smells sweet, the field smells sweet."

† Or "The (? sacred) fire-stick."

‡ The dialectic form of gištin, see pp. 20, note *; 29, 13.

§ Or "his little ones"—see rev., l. 10, of the extract on p. 18.

26. 'Ah' (would have been) the cry of woe(?)—'Alas' (if) the prince had remained.

---

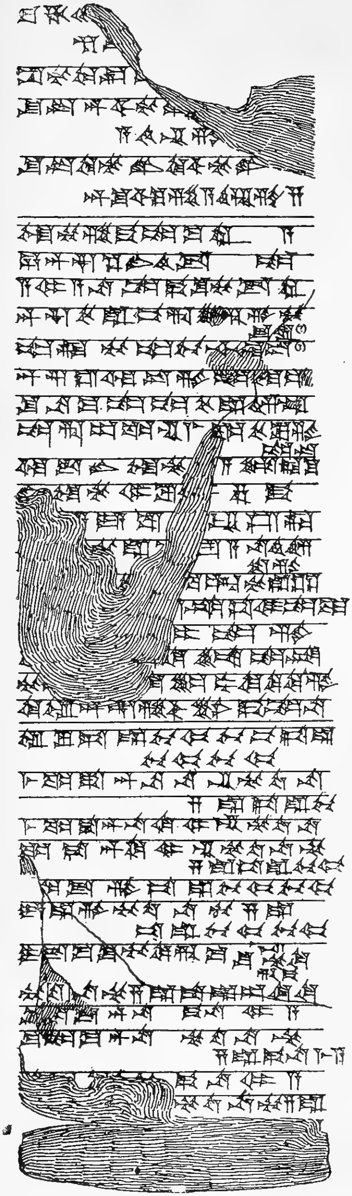
27. The lands thou hast plunged in gloom.
28. My husband, the barrier crossing by night—
29. The lands thou hast plunged in gloom.

As far as one can see from such a difficult inscription, and in the present defective state of our knowledge, the fifth column begins with a section in which the one lamenting—apparently Ištar, or one of her votaries, asks for various benefits, though whether 'the sceptre of glory' or 'the recompense of glory' was really included therein or not is doubtful—unless, indeed, the votary was a princess, which is not impossible. The short section which follows may be regarded as referring to the return of spring, with its more brilliant sunshine, after the short days of winter, and the words *Au*, *ašaba-da i-ru*, *ašaba-da i-ru*, 'Ah, he returns to the field, he returns to the field,' if my rendering be in any degree correct, may be regarded as confirming this.

The next section, which consists of 12 lines (the short ones being reckoned as belonging to the foregoing line) seems to contain praises of the god Tammuz, or, more correctly, of the place of delight where he was conceived as dwelling. This is followed by what seems to be a prayer for increase, named, from its first word, the 'Greatly'—a method of quoting and naming for which there are many parallels in Babylonian, as in other literatures, especially of the Semitic East. The burden of the 5 lines of this prayer seems to be to the effect that increase might be granted to all—the deity's house or temple, the offerings made to him, things which were young or small, and last, but not least, the suppliant herself. Between the ruled lines the former refrain is repeated: 'Ah, he returns to the field, he returns to the

COLUMN VI.

Text. *Transcription.*



1. Ba ḫa . . . .
si . . . .
2. Uš mu di-ma . . . .
3. Šu du an ši mu a[n šu û zi]
a-ḫi-en-gi [- za]
4. Šu du ki mu lu ki ši mu lu
5. an šu û zi a-ḫi-en-gi-za

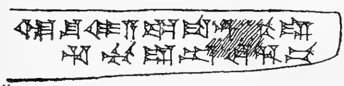
———————————————————————*

6. Nin-mu zi-ga-ne ba - ru - a
7. E (dimmer) Innanna nigin lu ḫi-da-ne
8. A mi a-na ne-ga-šu mu-da-ru
9. (dimmer) Innanna kur-ra-bi-ri in pag-gi mu-da-ru
10. Ur-la mu-ur-gu ti-la gin(?)
11. (dimmer) Innanna-gi û-du gi ne(?) nin(?) gi(š)
12. Šu na ma ne ne kur-ra im-me-ra
13. Ne ri ab ka en lal ka kura zu gi ne du
14. Û da lu nin-mu . . a-li-la-ku
15. Lu nin-mu mi zu . .† azag-ga
16. . . . a ia zu . . en lil-la
17. . . . . mu ? ra . . zu a na ḫi im te gi
18. . . . . kur . . ba-al mu ra gur-gur
19. . . . . maḫ ta mi ne nin‡
20. . . . . mi - ne - gi
21. . . . . di li ne maḫ
22. Mu . . . . . ki tu ub ki di di gi
23. Ki el (dimmer) Innanna zi ši in ga ne na

———————————————————————

24. El-lu ta-ra gu-ul-gu-ul§ ta-ra gu-ul-gu-ul
25. Me ka-ša an na-na en mu-ut-na za-ra ta-ra gu
26. Me ka-ša an-na di-mi en mu-ut-na
27. Ka-ša an di-mi en mu-ut-na-mu za-ra ta-ra gu-ul
28. Ne (?) da gi ta-ra gu-ul-gu-ul
29. I-gar-ra gi mu-ut-na-mu za-ra ta-ra gu-ul-gu-ul
30. I-da ma-šu mu-di-ri ma-šu mu-di-ri ga
31. Mu-[ut]-na-mu za-ra ša ra ab di di
32. . . ne(?) ma an na ga na mi a
33. Ma ne ma an na mu-ut-na-mu za-ra ga-na-me-a
34. . . . . ga-na-mi-a
35. . . . . mu-ut-na-mu za-ra
36. . . . .

LEFT-HAND EDGE.



1. Û šu mi a ka ša an ga(?) ra
2. ḫu-mu-ra-ab-di(?)-ḫu(?)-bi.

* A "corner-wedge" crosses this ruled line under *šu*.

† The traces here seem to be those of *mi*.

‡ From the peculiar writing, this might be also *ka*.

§ Written as *bi ;* by a mistake of the scribe.

field,' showing that the 'growth' referred to in this prayer must rather have referred to the produce of her fields than to the one making the request.*

The lines which follow seem to speak of Tammuz as he who had brought brightness to the suppliant, who (had the restorer of abundance after the unfruitful season of winter not returned) would have been in woeful case. The same theme is continued in the three lines of the next section, with which the column closes. It is to be noted that the suppliant here, as in other places, identifies herself with Ištar, whose spouse Tammuz was.

The last column is unfortunately too mutilated by a crack (which has damaged no less than 13 lines) to enable much to be made out of it, and I defer, therefore, for the present, any attempt to make a complete translation. Judging from what remains after the second division-line, however, it seems to contain an address to Ištar, the spouse of Tammuz. The following will serve to show that it resembles closely the portion already translated:—

6. My lady, he hath been taken away, bring him back.
7. Say, O Ištar, 'Return, man who bringeth plenty.'
8. From the waters of night who will bring him back to day?
9. Ištar will bring back him who was imprisoned in that land,
10. Lingering but free, returning alive.

. . . .

24. Hurrah, the spell is destroyed, the spell is destroyed!
25. Shout, lost one of Nana, lord, husband, the barrier, the spell, is destroyed, the spell is destroyed.

* The word which I have translated "increase" is the common root *su*, the Semitic *êrêbu*, "to increase," which occurs as the last component element of the *ideographic* writing of the name Sennacherib, namely, Sin-âḫê-êriba, "the moongod has *increased* the brothers." The temple of Tammuz at Agadé, where Ištar was likewise worshipped, was called Ê-su-gala, "the temple of the great increase."

26. Shout, lost one of Anu,—come near, lord, husband, the spell is destroyed, the spell is destroyed.
27. Lost one of heaven, come near, lord, my husband, the barrier, the spell is destroyed, the spell is destroyed.
28. Return thou hither(?), the spell is destroyed, the spell is destroyed.
29. Return to (our) domain, my husband, the barrier, the spell, is destroyed, the spell is destroyed.

The remainder of this column may eventually yield to further study, and in that case additional notes upon the text, and corrections of the renderings of the rest of the inscription, will be communicated. Other texts of the same nature and dialectic peculiarities, however, will be necessary to enable this to be done.

In attempting the translation of the above addresses to Tammuz, I have naturally used, wherever possible, such inscriptions as I am acquainted with of a similar nature. Of special value, as far as they went, were the glossary to the Semitic Story of the Creation, otherwise *the Story of Bel and the Dragon*, and the Hymns to Tammuz already known. The latter are mainly published in the *Cuneiform Inscriptions of Western Asia*, vol. iv., and naturally furnish valuable material for comparison. The following are renderings of these fragments, which, being sometimes provided with a translation in Semitic Babylonian, show how the people of those early ages understood them :—

4. The freshet, warrior, lord physician.*†
5. The freshet, my hero, my god Damu.*
6. The freshet, son, everlasting lord.*
7. The freshet, god Namgara, god Sa-diri.*
8. The freshet, director, lord of supplication(?)*

* The lines marked thus have no Semitic translation.

† The three lines preceding this are too fragmentary to translate. Lines 4 to 12 form the refrain to what preceded.

9. The freshet, god Gu-silim† with the tearful eye.*
10. The freshet, thou who art my prince of heaven.*
11. The freshet, Ama-ušumgal-ana.*
12. The freshet, brother, mother, wine of heaven.*

(Add. and Corr., p. 6.)

13. Shepherd, lord Tammuz, husband of Ištar.
14. Lord of the Underworld, lord of the shepherd's seat.*
15. Germ which in the furrow has not absorbed water.
16. Whose bud has not made a blossom in the meadow.
17. Sapling which has not been planted by its watercourse,
18. Sapling whose root has been removed.
19. Plant which in the furrow has not absorbed water.

. . . .

(Plate 27, No. 1).

4. The ewe and her lamb he nourisheth,‡
5. The goat and her kid he nourisheth ;
6. The ewe and her lamb he causeth to be slain,
7. The goat and her kid he causeth to be slain.*

---

8. Stop (?) the path (?), thou§ hero, to the road of no-return.
9. The freshet, warrior, lord physician,* etc., etc. (as in lines 4—12 above).
18. Go, go, to the bosom of the earth—
19. He will make plenty to overflow for the land of the dead,||
20. Filled with lamentation on the day that he fell, and (was) in distress,
21. In an unpropitious month of his year.¶
22. To the road of man's last end.**
23. At the call of the lord,††

* The lines marked thus have no Semitic translation.

† Gu-silim means (if rightly transcribed) "word of peace." It may, however, be connected with the characters translated "lost one," etc., in lines 12 and 13 of col. II., 17-20, 22, 23 of col. III., and in that case Kasa or Gusa would be more probable.

‡ The meaning of this word is slightly doubtful on account of the mutilation of the last character in the Semitic rendering.

§ "Thou" is wanting in the Semitic rendering.

|| Variant rendering : "Šamaš (the sun god) will make him grow for the land of the dead."

¶ Better, according to the Sumerian, "For the unpropitious month of *thy* year."

** Variant : "To the road of the people's rest."

†† Sumerian version, "his lord."

24. (Go,) O hero, to the distant land which is not seen.

---

25. Alas the growth which hath been cut off—alas the produce which hath been bound up.
26. The cry goeth forth, O shepherd, destruction is decreed.*
27. 'Where is his city?' the cry goeth forth.*
28. From the house of the enclosure one shall bring thee forth *—
29. Thou Hero, from the house of the enclosure one shall bring thee forth.*

Rev., l. 1. The freshet, warrior, lord physician,* etc., etc. (as in lines 4—12, above).

10. His little ones repose in the sunken ship.
11. His grown ones repose in the completed harvest.
12. The people repose in the hurricane.
13. . . . . without resting.
14. . . . .

(Plate 30, No. 2.)

The word translated 'freshet,' in the above inscriptions, is the Sumerian *ela* (written with the characters A-KALA, literally 'mighty water,') and is translated by the Semitic *ellu*, *milu*, and *înu*, the first two meaning 'flood,' or something similar, and the last 'well.' It will be remembered that, at the yearly feast of Adonis† held at Gebal or Byblos, when the river named after him (now known as the Nahr Ibrahim) ran red with the earth washed down from Lebanon by the autumn rains, they said that it was dyed with the blood of Adonis, slain, according to the legend, by a wild boar in the mountains

* The lines marked thus have no Semitic translation.

† The earliest reference to the Syrian *Adon*, *Adoni*, "lord," from which Adonis comes, is probably to be found on a cylinder-seal belonging to Lord Southesk. The text of the inscription which it bears (the order of the words is not quite certain) reads as follows: D.P. *Gištin* (?) *aduni mâr* D.P. *Šamaš Abdi-Addi rie* (or *riš*) *ili*, "Gištin my lord (or Gištin-adonis), son of Šamaš (the sun), Abd-Hadad the shepherd (or chief) of the god."

thereabouts. To all appearance the Babylonians kept this same festival, and it is evidently the rushing down of the overflowing waters which is referred to in the first word of the nine-line refrain contained in these extracts. The colour of the water in the Babylonian rivers, however, in all probability did not lend itself to the explanation that they were stained with the deity's blood, and the appearance of the autumnal floods in western Asia may merely have been regarded, originally, as a sign that summer was over, and that Tammuz was returning to his winter abode in the Underworld. Indeed, the name of Tammuz being of Babylonian origin, the old opinion that the legend concerning him originated in Syria would seem to be without foundation—the ruddy waters of the Adonis are to all appearance responsible for the transference of Adonis's fatal encounter with the boar to the mountains of Lebanon.

The date of the rise of the myth of Tammuz is doubtful, but as the name of the god is found on tablets of the time of Lugal-anda and Uru-ka-gina, who ruled about 3500 years B.C., it can hardly be of a later date than 4000 B.C., and may be much earlier. How popular it had become by the beginning of the second millenium before Christ the tablet belonging to the Manchester Museum has shown us, and many variants of the legend may, even at that early date, have come into existence. Unfortunately, the Assyro-Babylonian tablets have, as yet, given but few details of the myth, and even in the story of the descent of Ištar into Hades to seek the husband of her youth no statement as to the manner of his death occurs. As he is repeatedly called 'the shepherd,' and had a domain where he pastured his flock, Prof. Sayce sees in Tammuz 'Daonus or Daos, the shepherd of Pantibibla,' who, according to Berosus, ruled in Babylonia for 10 sari, or 36,000 years, and was the sixth king of the mythical period.* There is no doubt that, as pointed out by Richmond Hodges in his edition of Cory's *Ancient Fragments* (1876, p. 51, note) Pantibibla (Pantibiblon) is the Greek rendering of Sippar, the site from which, in all probability, the Manchester Museum tablet came. Concerning his successor, Enwedor-anchos,† some details are known, and it is therefore probable that (admitting the correctness of Prof. Sayce's identification) inscriptions recounting the adventures of Tammuz may likewise ultimately come to light.

The general likeness between the hymns to Tammuz already published and those of the Manchester tablet has probably been noticed—the principal difference seems to be, that the latter have no recurrent refrain. Any other departures from the style of the former which may exist are doubtless due to their being by a different author, who wrote upon a somewhat different aspect of the legend, and in a differing and possibly more rugged dialect. It is to be noted, however, that even the fragments preserved in the British Museum are not by any means easy to translate, notwithstanding that many of the lines are provided with a translation into Semitic Babylonian. Variants in the rendering of the old Babylonian scribes are given in the foot-notes on p. 17, but, in

*Another of his titles, "wine of heaven" (line 12 of the extract on p. 17). may have some reference to Col. V., line 13, but the doubtfulness of the reading in this latter passage is unfortunate, as nothing can be stated with certainty. Another text bearing upon this point is the cylinder belonging to Lord Southesk, referred to in the note (*) above, from which it would appear (if the reading and inferences therefrom be correct) that he was also called *Gištin* (=dialectic *Mutin*), "wine" simply. If he was god of wine, he would be the Babylonian counterpart of Bacchus, but perhaps he was only so entitled as he who brought the fertilizing streams from the mountains to rrigate the plains below. There was also a goddess called Mutin or Gištin, who is explained as "Lady of the plains."

† Various forms of this name occur in the Greek, all more or less incorrect.

addition to this, other discrepancies seem to occur. Thus, for example, line 20 of the extract from Pl. 30 of the *Cuneiform Inscriptions of W. Asia*, Vol. IV. (No. 2) 'filled with lamentation on the day that he fell, and (was) in distress' (in Semitic Babylonian *Nissatam mali ina ûm imqutu-ma ina idirtim*) is a rendering of the seven short words:—

Isiš - na - šu û šubba - na - šu
For his lamentation, for the day of his fall.

Were the Babylonian translators at fault here? It would seem so, for none of the other passages where the root *šubba* occurs imply that that word includes the idea of falling in or into distress. Of course, one cannot speak in such matters with certainty, but when we see that the translator (or was it merely the scribe?) has omitted the word 'his' in line 23 of the same extract, and translated 'his' instead of 'thy' in line 21, doubts as to the correctness of his renderings in other passages naturally arise. If, therefore, I have gone astray in my rendering of the Manchester Museum tablet—and there is no doubt that I have in many cases done so—I have at least one consolation and good excuse, namely, that of having sinned in good company, the company of the Babylonian scribes themselves. Moreover, it will be but little short of wonderful if I have even approximately hit upon the correct drift of the individual paragraphs.*

Since this paper was read, it has been thoroughly revised, and additions have been made thereto. The translations have also (it is thought) been somewhat improved, and a few additional lines of the sixth column of the Manchester tablet have been rendered into English.

* In the presence of so many homophones as Sumerian contains, one wonders how the people understood each other. In all probability they resorted to tones, as is done in Chinese, with which, as argued by the late Terrien de la Couperie and the Rev. C. J. Ball, Sumerian has close connection.

NOTES UPON THE WORDS.

COLUMN I.

1. The usual Sumerian word for 'place,' *ki*, is restored from line 3. *Ri*, in the dialect, is once rendered 'to pasture.' *Meme* is regarded as the plural of *me*, 'voice,' etc., a reduplicate like *kurkura* from *kur*. Col. V., last line. *Ma* is possibly a suffix. *Du* means 'to go"—*tum*, *gin*, and *ara* are also possible readings.

2. *Dikaša*, if it may be read, as is possible, *diduša*, possibly means 'to take,' Semitic *kašādu*. *Dinig* is equivalent to the Semitic *šapṣu*, 'strong one.' *Mea* means 'where,' and *ši* may be another way of writing *si* or *sig* (the character named *igi-gunu*), and if this be the case, the whole would be a variant of *meam-si*, which is translated *ali šû*, 'where is he?'

5. *Ḫaš-mara* seems to mean 'to make destroyed,' perhaps = 'to annihilate.' Tammuz became non-existent for Ištar when the queen of the underworld took him.

6. *Am* is one of the words meaning 'lord.' *Ḫili*, 'to rejoice, jubilate.' *Al-ma* are regarded as prefixes to *du*.

7. *Diri* is possibly a preposition—it is once given as equivalent to *êli*, 'over.' *Mutina*, 'husband,' *Gu*, 'to speak, command,' etc. *Salla*, 'to be broad,' hence *sallaba* is probably for *salla-bi-a*, 'in its fulness.'

8. *Gu-mudapad*, possibly from *gu*, 'to speak,' and *pada*, 'to call out,' *mu-da* being prefixed. *Ella*, 'glorious, clear.' *A-sudi* is possibly from *sud*, 'to be distant.'

9. *Zu*, 'to know,' with the prefix *an*, 'he (or she) who knows.' *Dibba* (*diba*), 'to take.' *Šu-nemala* is from *šu-mala*, 'to bow down, subjugate,' followed by *dim*, 'to make.'

10. *Mu-ne-in-mar-bi*, 'his name-making,' from *mu*, 'name,' and *mar*, 'to make.' *Me-in*, prefixes, *bi*, pronominal suffix. *Gi*, 'to return.'

11. *Ê*, 'to speak.' *Lu*, 'man, he who.' *Gala*, 'great.' *Naru*, probably for *nara*, 'singer.' *Ag-dila*, from *ag*, 'he who,' and *dili*, 'to record.'

12. *Ama*, 'mother.' *Šu*, 'hand, recompense, benefit,' also 'power.' *Ul*, 'joy,' also 'magnificence.' *Silim*, 'peace, well-being.' *Sisa*, 'to direct.' *Nu*, negation. *Pil*, 'to rest.'

15. *Gigiga*, reduplicate *gi*, 'to return,' with termination *ga*.

16. *Ba*, 'to grant, give.' *Ḫendu*, precative of *du*, 'to go, come.'

19. *Ag-gu* or *aga-gu*, 'he who calls.' The character *ag* in line 19 is written less fully than in line 21.

20. *Ḫula*, 'evil.'

25. *Ka*, 'mouth.' *Ta*, postposition.

27. *Mi*, 'night.' *Innanna*, the goddess Ištar in Sumerian. *Mura*, 'to enclose.' *Didi*, another form of the reduplicate root *dudu*, 'to go, come.'

28. *Ig*, the non-dialectic form of *ag* or *aga*, 'he who, that which.' *Azaga*, 'bright, pure.' *Ra*, postposition.

30. *Ig-gi* for *ig-gina*, Semitic *kîttu*, 'that which is fixed,' 'right, justice.' *Bara*, 'side.' *Gen* (*gi-en*), 'to be firm,' the same root as *gi*. *Im-tata*, reduplicate root *ta*, with verbal prefix. *Ta* means 'in, at, with, from.'

31. *Zara*, 'barrier,' *Dudu*. UL-UL, with this pronunciation, probably means 'to overthrow.' *Nu-umla* is probably for *nu-imla*, root *la*, once, according to Brünnow, *Classified List*, rendered *âmāru*, 'to see.'

33. *Nina*, 'lady, sister.'

Column II.

1. *Gin*=*magāru*, 'to obey.' *Ereš-ê-gala*=*Ereš-ki-gala*, in the 'Descent of Ištar,' and elsewhere. Compare p. 9.

2. *Zu*, 'to know,' here and in the forms *na-zu*, *nam-zu*, *ul-nam-zu*, *mun-zu*, *nane-zu* in the succeeding lines. *Men*, suffix, 'I am.' *Tu*, 'to enter.'

3. *Ru*. UL, with this pronunciation, is rendered by *napāku*, 'to break through.' *Da*, a termination.

4. *Na* is a variant of the negative *nu*.

5. *Igi*, 'eye, to see.' *Da*, a termination.

7. *Zarum* is apparently a variant of *zara*, 'barrier.' *Gigi*, reduplicate of *gi*, 'to stand firm,' hence, possibly, 'to hinder.' *Kur*, 'country.' *Bi*, demonstrative pronoun.

9. *Babar*, probably not the pronetic spelling of *babbara*, 'to be bright,' etc., but for *ba-bara*, from *bara*, 'high,' with the verbal prefix *ba*.

11. *Mi*, 'night.' *Da-du* is possibly for *dab-du* (line 15), 'to shut *Dadu* may, however, be the diadectic form of *kada*, 'to forsake,' or *du*, 'to walk, wander,' with prefix. *Diriši* may be either a longer form of *diri*, 'gloom,' or two words, *diri-ši*, for *diri-šu* (also written *-še*), 'in gloom.' But compare Col. V., lines 27 and 29.

12, 13, 34. *Kašanmen*, *kašamnana*, and *kašamen* all seem to come from the same root, with special suffixes, and have therefore been translated by the same word. For *kašanšaša* (read *dug-ša-an-ša-ša*), Zimmern, in his *Babylonische Busspsalmen*, p. 70, footnote, suggests the meaning 'demolishes him, whisks him away,' so that *kaša* or *duša* for (*dugša*) would probably mean 'captured,' and may be the latter part of *dikaša* or *diduša* in Col. I., lines 2 and 4.

14. *Ki*, 'place.' *Ria*, 'pasture,' see Col. I., lines 1 and 3. *Lu*, 'man,' and *šaga*, 'fair' = 'fair one.' *Gana*, 'come,' is elsewhere used as an exclamation, and therefore possibly so here. *Muti* for *mutina* (Col. I., line 7, etc.), 'husband.'

15. *Mi-šam* is possibly a form of *mi-šana*, the Semitic *šad muši*, 'midnight.' *Muda*, 'gloomy,' said of the day, and therefore, by extension, possibly of the night. *Igar* is probably for *ingar*, 'an enclosure.' *Dab-du*, apparently *du* (which may also be read *gin*), 'to shut in,' the Semitic *kalû*, with the prefixes *da-ab*.

16. *El*, the same as *ella*, 'pure, bright.' *Pad*, *pada*, 'to call, invoke.' *Dur*, 'to sit, to dwell.' *Ne*, 'to rest,' according to the glossary of the Creation-story, *Cuneiform Inscriptions of W. Asia*, vol. v., pl. 21, line 46. *Ku*, also pronounced *šu*, postposition 'to.' *Tum*, for *duma*, as in vol. ii. of the same work, pl. 29, line 28a, 'to go,' with prefix *bi*.

17. *Ninsue* is apparently the present tense of *su*, 'to increase,' with the prefixes *ni* and *in*—'it he increaseth.'

34. For *kašamen*, see above, to lines 12 and 13. *Mi*, 'night' or 'darkness.' *Sumunna* is apparently the same word as is used in the account of the evil spirits afflicting the moon, typical of an eclipse. *Ma* is apparently a suffix. *Šušugi* is somewhat doubtful, on account of the first character not being very clearly written, and *adšugi* is also a probable reading. *Šugi* is explained as *šêbu*, 'grey-haired man,' hence the rendering suggested. *Ad*, 'father,' would strengthen the idea, if that be the true reading of the first character. On the other hand, should the word contain the reduplicate root *šušu*, 'to descend, enter,' *šušugi-ta* would mean 'in descending.'

35. *Kanaga* is possibly the common root 'to bolt, seal up.' *Ši* would be the dialectic form of *zi*, 'life.' *Pad*, 'to announce,' with *gala*, 'to be,' suggests the rendering 'being announced.'

COLUMN III.

4. *Mea*. One of the many meanings of this word is 'to us.'

5. *Igi-zu*, 'thine eye.' *Igi* is not the dialectic form, which is *ine*.

6. *Šaba-zu*, 'thine heart.' *Šaba* dialectic for *šaga*.

7. *Giga*, one of the common words meaning 'evil.'

8. *Ne-tea*, 'he approacheth,' from *te*, 'to approach.' *Ne* is a pronominal prefix.

9. *Ennen-igi*, 'it (*enne*) he (*in*) hath seen (*igi*)—see line 5, and Col. II., lines 5. For *zu*, 'to know,' see Col. II., lines 2 ff.

10. For *el lu*, see Col. II., line 16. *Ama*, 'mother." *Mugib*, the dialectical form of *nugig*, 'hierodule,' an expression applied to the votaries of Ištar, and to the goddess herself. *Nigin*, 'to enclose, assemble' (*paḫāru*).

Ki el, as two words, means 'pure or glorious place,' but as one word, *kiel*, it stands for 'divine servant' or 'woman.' *Dadaga* is possibly the reduplicate root *da* with its lengthening, or the first *da* may be a prefix. In the glossary to the Creation-story, *Cuneiform Inscriptions of W. Asia*, pl. 21, lines 45 and 46, *da* is explained by the Semitic *lû* and *šakû*, 'may he be' and 'high,' hence the rendering adopted here.

11. *Ê-gala*, "great house, palace." The first component is not expressed, however, by the usual character, probably because the scribe wrote phonetically rather than ideographically. *Meta*, literally, 'from the voice,' or possibly, 'from us.' *Lu gala*, 'man great' = 'he who is great.' *Ḫula*, 'to rejoice.'

12. *Esi* appears once as a value of the character *kalaga*, 'strong,' and may therefore be regarded as a synonym, hence the rendering suggested here. *Pada*, 'to call, invoke.' *Zadu* is probably the same word as *zaduga* (*-dugga*) by loss of the termination *-ga*. It is translated by the Semitic *da'imu*, and is therefore a synonym of *muda*, line 15 of Col. II. *Da* is seemingly a post-position. It means 'with,' 'to,' and also, probably, 'in.' *Pil* (*pilla*) properly means 'to burn,' Semitic *qalû*, and as the character stands also for 'fire,' it is possible that 'light' may also be understood. More light, in the sense of critical material, is required upon this line, as, indeed, upon the rest of the inscription.

13. *Gišta* is explained by the Semitic *ṣêru*, 'plain, meadow,' and is here taken to mean Tammuz's domain, where he pastured his flocks. *Zu* is the usual suffixed possessive pronoun, meaning 'thy.' *Ig-zidiš* is a doubtful word, of which the first element, *ig*, 'that which,' is the only part which is clear. I have assumed for it the meaning 'that which delights.'

14. *Urma-zu*. The meaning of 'limbs' for *urma* has been adopted on account of *ur* having the meaning of 'limb.' *Ma* is probably the suffix already noted. *Ḫala*. One of the meanings of this root is *garāru*, 'to run.' *Muru*. One of the meanings of *gur*, which would be the non-dialectic form of this word, is *gabru*, 'strong,' or *kabru*, 'great,' and this may be the meaning here. *Muru*, however, has many other significations.

15. *Sir* has the meaning of 'light,' 'brilliant,' and 'perfect,' hence the rendering adopted. *Nam-ne-da-pada* is composed of the abstract prefix *nam*, two verbal prefixes (apparently), and *pada*, 'to speak, chant.' A portion of the text on this tablet may be referred to.

16. *Erim* is one of the usual words for 'enemy.' *Rušama* is apparently from *ruša*, in Semitic *êzēzu*, 'to be angry,' with the termination *-ma*.

17. For *kaša*, see the note to line 12 of Col. II. *Gišgallaka*, or *gišgallagu*, is the not uncommon word *gišgalla* with the termination *ka* or *gu*. It is equivalent to the Semitic *manzazu*, 'place, abode,' etc. As the ideograph for this word, provided with the prefix for man, and with the addition of the character *lu*, stands for 'man' in general, *gišgalla* must stand for the abode of man, namely, the earth.

19. *Ṭumu-giba*, 'Son of the flute,' is evidently one of the titles of Tammuz. I have not been able to find it in the lists. Upon the expression, see p. 9, note ‡.

20. *Ama-elaggi* also does not occur elsewhere, though future discoveries may reveal it. The value of *elag* or *ellag* for the character written in the form of a square is given by the tablets 80-11-12, 9 and 1488. It is rendered by the Semitic *kubbu* . . , perhaps to be completed *kubbutu*, which is one of its Semitic renderings. In this sense it probably means 'to honour,' suggesting for *Ama-elaggi* the meaning of 'honourable mother,' or 'mother of honour.'

21. *Ušu-gala*, usually written *ušum-gala*, means 'unique + great.' *A* is apparently the lengthening, *na* the possessive pronoun of the third person singular, and *ra* the postposition 'to, for,' etc., here, apparently, 'against.'

22. *Andu*, pronominal prefix, with root *du*, 'to go, come.' *Enneten*, restored by a careful comparison with the next line, is composed of the verbal prefixes *en-ne*, and the root *ten*, meaning 'to be calm, satisfied, at one's ease.'

23. I have regarded *Nana* as being shortened from *Innana*, one of the names of Ištar.

24. *Ši-umunna-gi* is composed of *ši*, the dialectic form of *zi*, 'life,' *umunna*, 'people,' and *gi*, the genitive suffix.

25. *Dusu* is one of the non-Semitic values of the group GAṬU, the meaning of which is 'to raise.' *Dusi* may therefore be a form of this word, meaning 'exalted.' *Unug* is the name of Erech, Semitic Babylonian *Uruk*.

26. *Mu*, meaning 'name,' indicates naturally the deity whose name was worshipped in a city, so that *dimmer mua* must be rendered 'tutelary divinity,' or something similar.

27. *Agu* is one of the words for 'crown, halo.'

30. *Egi* seems to be one of the words equivalent to *rubû*, 'prince.'

31. *Ua* is the usual word for 'to nourish.'

COLUMN IV.

1. The character *du* has been given its usual transcription when it means 't go,' but the character *ra*, which follows, may be its phonetic complement, in which case the two must be read together as *arra* (*ara*), a dialectic synonymous root.

2. *Agu*, 'crown, halo,' etc. *Šaba*, 'heart, middle.' *Ru*, possibly for *ra*, 'to, in.'

3. *Ul-mudanena*, apparently the root *ul*, 'to be bright, to shine,' and a cluster of suffixes. *Munnan* is the longest suffix of this kind hitherto found, whilst among the prefixed particles, which are analogous, *mudan-* occurs,

and only requires the additional letters *ena* to make it identical with the suffix in this and the following lines.

4. *Du* (which may also be read *ara*), 'to go, come.' *Abzu*, 'the abyss,' here written phonetically. *Igi*, 'eye,' is here used, possibly, for 'region,' like *igi kuram* (*Cuneiform Inscriptions of W. Asia*, vol. iv., pl. 15, in the tablet K. 111, end of Col. I., reverse, — the description of Eridu, the abode of the god Ea and of Tammuz). The full phrase is *ki igi kuram*, meaning 'it is the place of the eye (that is, the central region) of the land.'

5. *Nana* is possibly the reduplicate root *na*, 'to rest.'

6. *E-nun* is here taken to be for *a-nun*, 'the great water.' Several examples of the weakening of *a* to *e* occur, especially in words borrowed from Sumerian by the Semitic Babylonians.

7. *Azi* appears to be for *a-zida*, 'the right hand.' *Ibdi* is apparently composed of *ib*, 'he,' and *di*, Semitic *kašādu*, 'to advance.' *Zi*. One of the meanings of this root is 'to be bright, to dawn' (*namāru*, *napāẖu*).

8. *Ki* means 'place,' and is used for 'where.' *Indagu* is probably formed of the prefixes *inda*, 'he-with,' and *gu*, one of the values of the character *ku*, 'to dwell,' or short for *gub*, 'to remain.' *Eni* is probably a lengthened form of *en*, 'lord.'

9. *Sala-men* is composed of the character *sala*, 'woman,' with *men*, 'I am.' *Gu*, verbal root, meaning 'to speak.' *Šaru* is apparently the phonetically-written word *šara*, 'to cry out,' of which *šari* in the succeeding lines is a variant form. *Balagi* is the phonetic spelling of a somewhat complicated character of which the pronunciation is given as *balag*. Its meaning is 'lamentation.' *Almena* is a rather difficult word. To all appearance *al* is a prefix, here as in other places, giving the force of a participle. The best root to compare is one expressed by another rather complicated character (Brünnow's No. 3514), which is explained by the Semitic *zakû*, 'to be pure' and 'to set free.' The latter is doubtless the meaning required.

11. *Ši* is here apparently a variant of the *še* in line 19, which is explained in the lists by *šēmû*, 'to hear.' The meaning seems to fit.

13. *Sisa*, 'to direct,' see Col. I., line 12.

15. *I* is one of the words rendered by the Semitic *na'ādu*, 'to exalt, praise,' etc.

17. For *gu*, see line 9. *Še* is the usual word for 'seed,' especially wheat. *An-sura*. This is apparently the verbal prefix *an*, with the root *sura*, one of the meanings of which seems to be 'to come through,' the crack of a door, etc. In *muna-ila-ta* may be seen the verbal prefixes *mu-na-* (perhaps for *mu-na-ab-*), with *ila*, 'to come forth, rise,' etc. *Ta* is the postposition meaning 'from,' here used, as elsewhere, in the sense of 'after.' *Lummi* is apparently a form of *lumma* (*luma*) 'to grow,' of plants. *Mimma*. As the character expressing the root *sal* means 'to be broad,' it probably has a similar

meaning likewise with the pronunciation of *mim*, in which case *mimma* would signify something like 'crop, harvest.' *Mu* is the possessive pronoun of the 1st person singular. *Meden.* Possibly the root *med*=non-dialectic *gid*, 'to draw, bring,' and also, seemingly, 'to yield up,' Semitic *šadādu*. *En* is a common verbal suffix expressing the 2nd person of the singular.* *Nuliš*. From the termination *-iš*, this should be an adverbial form, in which case the root would be *nuli*. The sense required by the rendering adopted is 'plentifully,' or something similar, and if the inscription was written under Semitic influence, the value of *la* for *nu* might be suggested, and would be justified by two passages in Brünnow's *Classified List*. *Lališ*, from *lal*, 'plentiful,' which this would give, expresses the idea which seems to be needed. Perhaps, however. *nuliš* is written for *luliš*, in accordance with a phonetic rule of the language, and in that case we should have simply a variant form.

19. The first *še* is apparently the root corresponding with the Semitic *šemû* 'to hear.' *Ši* in line 11 is a variant of this. The second *še* is the word for 'grain.'

20. For *i*, see the note to line 15.

21. *Si-ki* is here written for *si-sa*, as is proved by line 13.

22. *U* is the usual word for 'and,' often transcribed *ša*. *Ama-mu*, 'my mother,' unless the *mu* be the prefix to *pada*, in which case the translation would be 'and the mother invoketh.'

23. *Nin*, 'lady,' also 'sister.' *Mu* in all probability originally existed after *ama*, so that '[my] mother' may be regarded as a better rendering.

25. *Ud-da* is explained by *šumma*, 'when,' literally, 'on the day.' The division-line between lines 25 and 26 has been omitted in the copy by mistake.

26. For the completion of this line, see lines 9 and 22 of Column V.

29. *Šiš* is the usual word for 'brother.'

30. For *mut*[*na*] 'husband,' see Col. I., line 10.

COLUMN V.

3. *Za* is a variant of *zu*, 'thy.'

4. *Gi*, 'reed,' probably stands also for 'sceptre.' *Ag-egi* is possibly composed of *ag*, 'he who,' and *egi*, which, as shown in the note to Col. IV., line 30, probably means 'prince.' *Gi ag-egi* would therefore mean 'the sceptre of him who is prince.' *Abba*, in its commonest acceptance, means '*grey*-haired old man,' Semitic *šêbu*. *Ḫia* is also a common expression, the rendering of which, 'let it be,' hardly admits of doubt.

5. For *mimma*, see Col. IV., line 17. *Banda* is a word of somewhat doubtful signification, but there seems to be no doubt that it contains an

*Compare Col. V., line 8.

allusion to the perfection and strength of youth, the ideograph with which it is generally expressed being composed of the character for 'young' followed by that for 'strong.' Semitic *ašṭu.*

6. For *ki el*, see the note to Col. III., line 10. *Ašni.* Of this word I have not come across a probable explanation.

7. Various explanations for *u-da am* and *u-da didi* are possible, but as the remainder of the line is practically the same as line 18 of Col. IV., one would expect something of the nature of field-produce to be referred to—as, in fact, the syllable *u*, with which the two groups begin, indicates. It may therefore be conjectured that these words stand for two kinds of vegetable food used by the Babylonians. In *emidi* we have what may be regarded as a confirmation of the explanation of *meden* given in the note to Col. IV., line 18, *e* being a Sumerian prefix meaning 'thou,' and *midi* (written for *medi*) the root of *meden.* As already remarked, it is probably the dialectic form of *gid*, 'to bring along.' *Nuliš* has already been discussed in the note referred to.

9. *Au* seems to be an exclamation, corresponding either with 'O!' or 'ah!' *Ašaba* is the commonest word for 'field,' and *da*, which follows it, seems to be a post-position, with the meaning of 'to.' It is possible, however, that this *da* may be the prefix to the word *iru*, which follows. With regard to the latter, a considerable amount of doubt exists as to the root, whether it be *ru*, one of the meanings of which is 'to return,' or *ir*, 'to smell sweet.' In the latter case, *da* would be the verbal prefix.

10. *Giš-izi* means, literally, 'wood of fire.' *Lu* is the usual word for 'man.' *Zi*, 'faithful,' is for *zida.* *Di*, with the pronunciation of *silim*, is equivalent of the Semitic *šalmu*, 'perfect, luckbringing, right.' *Ig-mara-zu-ku* is apparently formed of *ig*, 'that which,' *mara*, 'to sit,' *zu* 'thy,' and *ku* or *šu*, 'to.' *Ig-mara* would therefore mean 'that which is a seat,' or 'dwelling.'

11. *Zidamen* is composed of *zida*, 'true, faithful, everlasting,' and the suffix of the second person singular. The *ku* at the end of the line has somehow disappeared.

12. *Umun* is the usual dialectic word for 'lord.' *Guli* is probably a form of *gala*, 'great,' also spelled *gula.* *Ana* is explained by the Semitic *mala*, 'as much as.'

13. *Mu-til.* The second character of the name is one which I have not been able to find in this exact form elsewhere, but it seems to be that for 'wine,' *gištin*, with an extra wedge at the beginning. If this be the case, it is either used with a phonetic complement *mu* at the beginning, or else (as is more probable), it has here simply the value of *til.* As will be seen from the reference to the cylinder in the possession of the Earl of Southesk, the reading of *Mutil*, the dialectic form of *Gištin*, would seem to be certain.

14. *A-zida*, 'the right hand.' *Êa*, 'house.' The character *e* is doubtful, and the rendering, therefore, uncertain.

15. *Ê para*, literally, 'house of the shrine.' *Ga-ria*. A form of the precative particle *ḫa*, with the verbal root *ri*, 'to found.'

16. *Magala* is an adverb translated by the Semitic *ma'idiš*, 'greatly,' and is formed of the root *gala*, 'great,' with the prefix *ma*. *Giš-gu* shows another form of the precative *ḫa*, with *gu*, 'to speak.' *Ma* is apparently a particle, possibly meaning 'so, then.' *Gam-su* seems to be formed of the precative prefix *ga*, the pronominal particle *am*, and *su*, 'to increase.'

17. *Su*, 'increasing,' the root of *gamsu* and *gasu*. *Ê*, 'house,' without the lengthening *a* (see line 14). *Ga-su* would seem to be the same form as *gam-su*, but without the infix *am*.

18. *Sura*. Probably the *sur* (so read instead of *zur*) of Brünnow's *Classified List*, Nos. 3708—3710 (the last has the phonetic complement *ra*, showing that the word was read *sura*) and the *surru* of Nos. 3712—3714. The word stands for a class of priests, here, in consequence of the context, rendered 'sacrificer.' *Kinene*. The characters *kine*, in Brünnow, No. 9690, are indicated as being pronounced *gunni* and *ne*, pointing to the alternative pronounciations of *gunne* and *nene* (the second *ne* in our text being evidently the pronetic complement). As, however, this is a dialectic text, in which the vowel *e* often takes the place of the *u* of standard forms, and is written mainly phonetically, the natural transcription of the characters has been retained. The meaning of the Semitic *kinunu* (borrowed from Sumerian) is 'brazier,' and Delitzsch quotes a passage in which a 'movable brazier,' apparently a censer, is referred to, indicating that something of the kind is intended here. To all appearance the vessel in which the offering was made stands for the offering itself. *Bi* is here the possessive pronoun.

19. *Aga-turtur*. *Aga*, 'that which,' and the reduplicate root *tur*, 'young, small.' *Maššu*, Semitic form *maššu*, seems to mean 'hero, supreme one,' or something similar.

20. *Salla*. As one of the meanings of this root is 'to be broad,' 'fulness,' or something similar, would seem to be the meaning required here. *Ê-gia* is rendered by *bît nakmitum*, probably 'house of enclosing, cloister,' *bît têliltum*, 'house of purification,' and *bît kilûtum*, 'house of burning,' possibly meaning the place where incense was burnt for the purposes of ceremonial purification, a statement which would agree with the proposed rendering of line 18. *Susu* is taken to be the reduplicate root *su*, 'to increase.'

21. *Ig-ba* means 'that which is presented,' and may refer to an offering made in the temple. *Imma-tia* apparently means 'he has received,' from *ti*, 'to take,' with the pronominal prefixes *im-ma*. *Ta* is a postposition with the meaning of 'after,' as in lines 17—21 of Col. IV. For *mimma*,

see the same, lines 17 and 18. *Gigam* is, perhaps, for *gigiam*, the reduplicate root *gi*, 'to return,' with the termination *am*, the phonetic reproduction of the ending elsewhere written *a-an*.

23. *Mi*, 'night, dark.' *Ki el*, 'place pure,' or, perhaps, as in the translation, place of purification. *Isidinamen* I have regarded as a verbal root with the termination of the 2nd person singular *-en*, as in Col. IV., line 18, the rendering 'to make brilliant' having been chosen on account of *babariden*, which seems to be for *babbariden*, and, therefore, probably, from *barbar*, 'to be bright.' Both, however, are exceedingly long for Sumerian verbs, and the renderings indicated must be regarded as extremely doubtful. As *isi* may mean 'weeping,' it is possible that *mi isi dinamen* means 'thou hast sent away (*din* for *gin*=*šapāru*), the night of weeping,' and the following word might also be explained as *babari dien* or *den*, 'bright one, thou comest.'

24. *Subadamen* in this line is an equally difficult word, and may also really be two.

25. *Mimma-mu nudumen* may also be read *mimma munudumen* and *mimma munu dumen*—probably the latter, as *munudumen* would be altogether too long. *Munu* would regularly be the dialectic form of the common word *gun*, 'profit, gain, tribute.' The reading of the printed transcription, however, seems to be the best.

26. *A* is the exclamation corresponding with 'ah,' and is parallel with *ua* in the second half of the line, which corresponds with 'woe, alas.' *Idib* is rendered by the Semitic *qubû*, 'word, cry.' *Sulagine* is a word which presents considerable difficulty, and the rendering given is little better than a guess. Perhaps the true reading is:

A idib sula gine — ua nunu madu
'Ah,' the voice of the hero returns—'Alas,' the prince replies.

Gine would be from *gi*, 'to return,' *nunu*, 'great one, prince,' and *madu* from *du*, 'to bring back,' though 'reply' is a sense not elsewhere found for this root. *Sula* is a dialectic word with a somewhat loftier meaning than the Latin 'vir.' Naturally, if this rendering be in any way correct, that of the preceding lines is wide of the mark.

27. *Kurkurra* is restored from the traces and from line 29. For *dirišamen*, compare Col. II., lines 11—13. The ending *-men* or *-amen* contains that of the 2nd person singular.

28. The restoration *mutna* may be regarded as practically certain. For *zara*, see Col. I., line 31. *Gana* would seem to be the same word as in line 14 of Col. II., not used, however, as an exclamation. If *zara* means 'barrier,' then 'crossing,' or something similar, ought to be the signification of *gana*. Whether the terminal *a* of *mia* has the force of a postposition or not is uncertain, but the meaning of the word seems to be as rendered.

COLUMN VI.

6. *Nin-mu*, or *ereš-mu*, 'my lady.' *Zigane* is from *ziga*, 'to remove.' *Barua.* The root of this word is *ru*, 'to return,' with the prefix *ba.*

7. *Ê*, the Semitic *qabû*, means 'to speak.' *Nigin*, 'to enclose,' also 'to turn again.' *Lu*, 'man, he who.' *Ḫidane*, a doubtful word.

8. *A*, the usual word for 'water.' *Mi*, 'night,' frequent in this text. *Ana*, 'who,' according to *Cuneiform Inscriptions of Western Asia*, vol. iv., pl. 11, line 16. *Nega-šu*, apparently a noun with the postposition *šu*, 'to.' *Nega* or *Negae* is explained, loc. cit., pl. 5, line 66 ff., as being equivalent to *Urru*, 'day.' *Mudaru.* The root *ru*, with the prefixes *mu-da.*

9. *Kurra-bi-ri* is construed as 'to his land,' *bi* being the pronominal suffix 'his,' and *ri* for *ra*, 'to.' *Pag* means 'to cage birds,' and might, by extension, be applied to men. The form *in-paggi*, instead of *pagga* (*paga*), would be analogous to *šari* in Col. IV., line 10 ff.

10. *Ur-la* is explained in the lists by *ûḫḫuru*, 'to be left behind,' or something similar. *Murgu* is given as the equivalent of *padû ša âweli*, 'to spare, used of a man,' meaning here, possibly, 'to allow to go free.' *Tila* is the common Sumerian root for 'to live.' *Gin* is one of the many values of *du* in the meanings of 'to go, to come,' etc.

24. According to Delitzsch, *Assyrisches Handwörterbuch*, under *lallartu*, *ellu* is a cry of triumph similar to 'hurrah.' *Tara* means 'to cut' and 'to decide,' hence, also, to fix one's fate (Semitic *šâmu*). *Gulgul* is the reduplicate root *gul*, 'to destroy' (*âbātu*). *Tara gulgul* would therefore seem to mean 'the ban is utterly destroyed,' or something similar.

25. As a parallel to *ellu*, *me* is also, probably, a kind of exclamation meaning 'shout,' from *me*, 'voice, to call out,' etc. *En* or *eni*, 'lord, as in Col. IV., line 8. It is here ideographically written. This line, like those which follow, has to be completed in accordance with line 24.

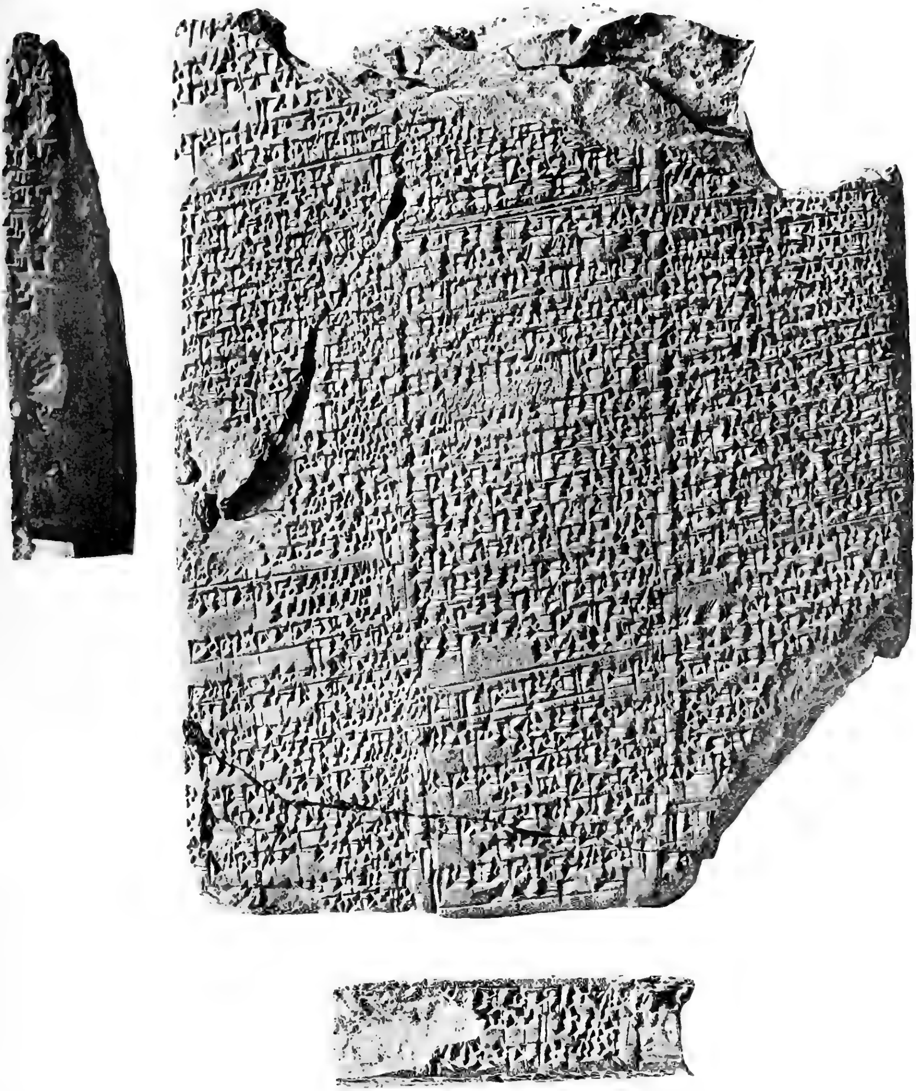
26. *Anna* is the usual Sumerian way of writing the name of the god of the heavens, Anu. *Dimi* I take to be the Sumerian root corresponding with the Semitic *sanāku*, 'to draw close to.'

27. The rendering of *an* after *kaša* is difficult to decide, and is perhaps best regarded as a termination to that word, as in Col. II., line 12.

28. The first half of the first sign is broken away, but what remains suggests the character *ne*, in which case *ne-da* may be similar in meaning to *nēta*, 'in this,' meaning, with the following *gi*, 'return to this place,' or something similar.

29. Here, as in Col. II., line 15, it is perhaps best to regard *igar* as indicating an enclosure of some kind. *Ra* is construed as the postposition meaning 'to.'

Tablet inscribed with Hymns to Tammuz.
(Obverse, and right-hand edge with the ends of the lines of Column III.)



Tablet inscribed with Hymns to Tammuz.
(Reverse, with the text continued on the lower and left-hand edges.)

PROCEEDINGS

OF

THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

Ordinary Meeting, October 6th, 1903.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The following books were included amongst the recent donations to the Society's Library:—"*Subject List of Works on Architecture and Building Construction*" (8vo., London, 1903); "*Guide to the Search Department of the Patent Office Library*," 2nd ed. (16mo., London, 1903), presented by the Patent Office, London; "*Tibetan-English Dictionary*," by Sarat Chandra Das, revised and edited by C. Sandberg and A. W. Heyde (4to., Calcutta, 1902), presented by the Lieutenant Governor of Bengal; "*A Historical Sketch of the Experimental Determination of the Resistance of the Air to the Motion of Projectiles*," by F. Bashforth (8vo., Cambridge, 1903), presented by the author; "*Catalogue of Canadian Birds*," Pt. ii., by J. Macoun (8vo., Ottawa, 1903), presented by the Geological Survey of Canada; "*Natick Dictionary*," by J. H. Trumbull (8vo., Washington, 1903), presented by the Bureau of American Ethnology; "*Great Trigonometrical Survey of India*," vol. xvii. (fol., Dehra Dun, 1901), presented by the Secretary of State for India; "*Le Opere di Galileo Galilei*," vol. xiii. (4to., Firenze, 1903), presented by the Italian Government; "*Catalogue of the Library of the Literary and Philosophical Society of Newcastle-upon-Tyne*," (4to., Newcastle-upon-Tyne, 1903), presented by the Committee of the Society; "*Report on the Collections of Natural History... of the 'Southern Cross,'*" (8vo., London, 1902); "*Guide to the Coral Gallery...in the British Museum (Natural History)*" (8vo., London, 1902); "*Handbook of Instructions for Collectors,*" (16mo., London, 1902), presented by the Trustees of the British Museum; "*Reports of the Sleeping Sickness Commission,*" No. 1. (8vo., London, 1903); "*Reports to the Malaria Committee,*" 8th set (8vo., London, 1903), presented by the Royal Society of London.

Dr. HENRY WILDE, F.R.S., read a paper entitled, **"On the Resolution of Elementary Substances into their Ultimates and on the Spontaneous Molecular Activity of Radium."**

Mr. THOMAS THORP, F.R.A.S., exhibited a specimen of about six milligrams of radium bromide, and showed its effects on a barium platino-cyanide screen in the dark; a Crookes's spinthariscope; and a photograph of the head of the late Queen taken through the substance of a copper coin from which the reverse had been ground away.

Mr. THORP also mentioned that a minute quantity of the radium salt mixed with zinc sulphide and a little gum water made an excellent luminant for noting the time when applied to the hands of a watch in the dark.

A paper by Mr. E. A. NEWELL ARBER, M.A., F.L.S., F.G.S., entitled, **"Notes on Fossil Plants from the Ardwick Series of Manchester,"** was communicated by Professor F. E. WEISS, D.Sc., F.L.S.

General Meeting, October 20th, 1903.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

Mr. HENRY GUPPY, M.A., Librarian of the John Rylands Library; Mr. JONATHAN BARNES, F.G.S., Higher Broughton;

Dr. F. CRAVEN MOORE, M.Sc., Assistant to the Professor of Medicine, Owens College; Mr. J. LEWIS PATON, M.A., High Master, Manchester Grammar School; Mr. W. H. CORE, M.Sc., Withington; and Mr. H. E. WOOD, B.Sc., Demonstrator in Physics in the Owens College, were elected ordinary members of the Society.

Ordinary Meeting, October 20th, 1903.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The bust of John Dalton, presented to the Society by Sir Henry Roscoe on the occasion of the Centenary of the Announcement of the Atomic Theory, was unveiled by the President. The Secretary read the following letter from the donor:—

"I desire to present to the Literary and Philosophical "Society of Manchester a bronze bust of Dr. Dalton, as a "memento of the years of pleasant intercourse which I have in "past days spent in converse with its members, and as a "recognition of the honour which the Society has done me by "electing me as an Honorary Member, and in bestowing upon "me its Dalton Medal. The bust is the work of a distinguished "sculptress, Miss Levick, and I believe that all those who have "seen it agree with me in esteeming it a powerful and lifelike "work of art. It will give me great satisfaction to hear that the "Society accept my gift, and that they value the bust as a work "of art, and as a reminiscence of the donor."

The PRESIDENT then formally unveiled the bust, and said that there were two sources used in the construction of it—one a bust executed by Chantrey in 1833, representing Dalton when 67 years old; the other a little ivory statuette formerly the property of Dr. Bealey, but presented by him at the suggestion of Mr. Francis Nicholson to the Society. The President made reference to a silhouette portrait of Dalton given to the Society that same evening by Mr. Arthur McDougall, B.Sc., the Hon. Treasurer, and mentioned further that it was a happy coincidence that this meeting took place on the anniversary of the date (October 21st, 1803) when Dalton communicated to the Society his paper "On the Absorption of Gases by Water," in which the first hint of the Atomic Theory was given.

The book containing the minutes for 1803, which records the communication of the paper and its acceptance for publication, and also the volume of the Memoirs published in 1805 in which the paper was printed, were passed round for inspection.

Mr. HENRY SIDEBOTTOM read a paper entitled, "**Recent Foraminifera from the Coast of the Island of Delos,**" in which he enumerated some 70 species of Miliolidæ, including four new species and several interesting variations. The new species and variations were fully described, and drawings both of the specimens and their sections exhibited. Mr. Sidebottom stated that the dredgings from this locality were extraordinarily rich in Foraminifera and that he hoped to complete the description of the whole series.

General Meeting, November 3rd, 1903.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

Mr. S. H. CAPPER, M.A., Professor of Architecture in the Victoria University of Manchester; Mr. H. S. NEWBOULD, B.A., Assistant Master at the Manchester Grammar School, were elected ordinary members of the Society.

Ordinary Meeting, November 3rd, 1903.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. Among the recent donations to the Society's Library were the following :—"*Untersuchung über die Eigenbewegung von Sternen in der Zone 65°—70° Nördlicher Declination*," von J. H. Schroeter (4to., Christiania, [1903]), presented by l'Observatoire de Christiania; "*Bacteria and the Nitrogen Problem*" (8vo., Washington, (1902)), and "*The Contamination of Public Water Supplies by Algæ*" (8vo., Washington, (1902)), by G. T. Moore, presented by the Author; "*Lancashire Pipe Rolls and Early Charters*" (4to., Liverpool, 1902), and "*A History of the Parish of North Meols*" (4to., Liverpool, 1903), by W. Farrer, presented by the author.

A collection of wind-worn pebbles of quartz and quartzite from an old raised beach near Waverley, North Island, New Zealand, together with photographs, was exhibited by the President. They have been cut by the sand driven by the wind into the characteristic *Dreikanter*, and might easily be mistaken for the work of the hand of man. The direction of the prevalent winds is shown by the amount of work done on each side or facet, the texture of the wind-worn being quite different from that of the wave-worn surfaces.

The collection and the photographs were made by Lady Constance Knox in 1900, and were afterwards given by her to the Manchester Museum, Owens College.

Mr. H. E. SCHMITZ, M.A., B.Sc., read a paper entitled, "**On a Method of Ice Calorimetry.**"

General Meeting, November 17th, 1903.

Professor H. B. DIXON, M.A., F.R.S., Vice-President, in the Chair.

Mr. CHARLES W. E. LEIGH, Deputy Librarian, The Owens College; and Mr. J. H. W. WORTHINGTON, B.A., were elected ordinary members of the Society.

Ordinary Meeting, November 17th, 1903.

Professor H. B. DIXON, M.A., F.R.S., Vice-President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The following were among the recent donations to the Society's Library:—"*On the Recent Geological History of the Bergen District of Norway*," by H. W. Monckton (8vo., 1903), presented by the author; "*Justus von Liebig nach dem Leben gezeichnet*," von G. F. Knapp (4to., München, 1903), and "*Ueber wissenschaftliche Wahrheit*," von K. A. v. Zittel (4to., München, 1902), presented by the K. B. Akademie der Wissenschaften zu München.

Mr. CHARLES LEIGH presented to the Society a framed engraved portrait of Dr. John Dalton, drawn by J. Stephenson.

Professor LAMB exhibited and described two photographs, taken at the Isle of Man by Mr. Hiller, one of which showed very clearly the interference between the direct and reflected waves on the sea-coast. The points of intersection of the two systems of waves were particularly well marked.

Mr. THOMAS THORP, F.R.A.S., exhibited a small glass tube containing a little radium bromide at the sealed end, and terminating at the other in a bulb. The whole formed a vacuum tube, and made a very convenient and portable apparatus for showing in the dark the fluorescence of a barium platino-cyanide screen in the presence of radium bromide. He also stated that the bulb caused a charged electroscope to very rapidly discharge.

Messrs. R. S. HUTTON, M.Sc., and J. E. PETAVEL described some experimental work which they had undertaken in order to study the effect of high gaseous pressures upon electric furnace reactions. The investigation was being carried out in the Electro-chemical Laboratory of the Manchester University. The preliminary results only were given, progress having been necessarily slow up to this time. The several dispositions of the furnace and of the arcs were described, and photographs of them thrown upon the screen.

The subject was, they said, an exceptionally wide one, and in view of the increasing importance of the technical applications of the electric furnace, the results might prove not only of scientific interest, but also of practical value.

To obtain really satisfactory results, it was necessary to exceed what is usually considered the laboratory scale of operations. Consequently a plant of considerable size had to be installed, which was rendered possible by a grant from the Government Grant Committee of the Royal Society.

For the present the work had been confined to the production of calcium carbide, aluminium and nitric acid, as effected by pressures up to 150 atmospheres.

An interesting discussion followed, in which several members took part.

Ordinary Meeting, December 1st, 1903.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The following were among the recent accessions to the Society's Library:—"*Reports of the Sleeping Sickness Commission*," Nos. 2-4 (8vo., London, 1903), presented by the Royal Society of London; "*Subject List of Works on the Mineral Industries and Allied Sciences*" (16mo., London, 1903), presented by the Patent Office, London; "*Monograph of the Coccidæ of the British Isles*," vol. 2, by R. Newstead (8vo., London, 1903), purchased from the Ray Society.

The PRESIDENT drew the attention of the meeting to the fact that, although the rainfall during the last six months had been unusually heavy, the water in the deep springs had not increased proportionally, but was still below the average quantity for the last ten years.

Dr. W. E. HOYLE, F.R.S.E., exhibited a model of the mole's nest, prepared by Mr. Lionel E. Adams and presented by him to the Manchester Museum. Mr. Adams read a paper on the subject before the Society on November 18th, 1902. The model is in three parts, and shows the construction of a typical nest of the male mole very clearly.

The lower part of the base contains a circular cavity for the nest with several outlets just below the surface. Immediately above this, but not in any way communicating with the nest or with the tunnels leading from the nest, is another series of channels or runs. Above this again is the familiar mound or mole-hill, being made up of the soil which is forced upwards during the work of excavation and tunnelling beneath the surface.

Mr. F. F. LAIDLAW, B.A., read a paper entitled, "**Suggestions for a Revision of the Classification of the Polyclad Turbellaria.**"

General Meeting, December 15th, 1903.

CHARLES BAILEY, M.Sc., F.L.S., in the Chair.

Dr. BERTRAM PRENTICE, Lecturer on Chemistry, Royal Technical Institute, Salford; the Rev. H. J. GRAHAM, M.A.; Mr. R. B. FISHENDEN, Lecturer in Photo Mechanical Processes at the Municipal School of Technology; Mr. NORMAN WEST, A.I.E.E., Electrical Engineer; and Mr. W. T. MACCALL, M.Sc., Demonstrator in Engineering at the University of Manchester, were elected ordinary members of the Society.

Ordinary Meeting, December 15th, 1903.

R. L. TAYLOR, F.C.S., F.I.C., in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Professor EDMUND KNECHT, Ph.D., read a paper entitled, "**An Interesting Reaction of Copper Salts.**"

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., read a paper entitled, "**On the Electrolytic Method for the Detection and Approximate Estimation of Minute Quantities of Arsenic in Malt, Beer, and Food Stuffs.**"

General Meeting, January 5th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

Mr. E. H. LANGDON, Merchant, and Mr. A. D. DARBISHIRE, B.A., Assistant Lecturer and Demonstrator of Zoology in the University of Manchester, were elected ordinary members of the Society.

Ordinary Meeting, January 5th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The following were among the recent accessions to the Society's library:—"*Vogul Népköltesi Gyüjtemény,*" 1 Kötet et Kiegészitö füzet. (8vo., Budapest, 1902.) [Collection of Popular Poems of the Voguls. Fasc. I. and Suppl.], presented by the Magyar Tudományos Akadémia; "*Topographical Maps of Assiniboia, Saskatchewan, Alberta, Banff, and Lake Louise*" (Ottawa, 1903), presented by the Department of the Interior of Canada; "*Original Papers,*" by the late John Hopkinson. Ed. by B. Hopkinson. 2 vols. (8vo, Cambridge, 1901), presented by the Syndics of the Cambridge University Press; "*Bibliographia Geologica,*" Sér. A. Tome vii. and Sér. B. Tome vi. (8vo., Bruxelles, 1903), purchased; "*British Tyroglyphidæ,*" vol. 2, by A. D. Michael (8vo., London, 1903), purchased from the Ray Society.

The SECRETARY announced that the Council had decided to photograph some of the apparatus belonging to Dalton, and used by him in making his researches. Mr. C. L. BARNES, M.A., read a letter from the late Dr. Schunck stating how the apparatus came into the Society's possession.

Mr. R. L. TAYLOR, F.C.S., F.I.C., communicated the following

"Note on a Method of preparing Hydrobromic Acid."

It is well known that when a bromide is acted upon by strong sulphuric acid, a mixture of hydrobromic acid and free bromine is produced, the formation of the bromine being due to the action of the hydrobromic acid and sulphuric acid upon each other, sulphur dioxide being produced at the same time:—

$$H_2SO_4 + 2HBr = SO_2 + 2H_2O + Br_2.$$

If however a little amorphous phosphorus is mixed with the bromide, and a little water added, strong sulphuric acid liberates hydrobromic acid which is quite colourless and contains no free bromine. By this method the acid may be prepared in quantity just as easily as hydrochloric acid can be obtained by the action of strong sulphuric acid upon common salt.

The hydrobromic acid prepared in this way is not perfectly pure; it always contains a small quantity of sulphur dioxide. For most purposes the presence of this impurity would not matter, but, if the acid is required to be perfectly pure it may be first passed into water, the small amount of sulphurous acid oxidised by a little solution of potassium permanganate, and the solution redistilled.

Ordinary Meeting, January 19th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT announced the death of Dr. Karl Alfred von Zittel, Professor of Palæontology and Geology at Munich, and an Honorary Member of this Society, which took place on January 5th, 1904.

The PRESIDENT exhibited two specimens of chalcedony containing enclosed water, and described the mode of their formation by a continued deposition of siliceous layers inside a cavity in a volcanic rock. When there is no empty space left the stone is called an agate.

The President also stated that onyxes were invariably of artificial formation, the method adopted in former times being to saturate a portion of a chalcedony with honey, and to heat the mass till charring took place, and in modern times to employ sugar and strong sulphuric acid for the same purpose.

Mr. H. E. SCHMITZ, M.A., B.Sc., read a paper entitled, "**On the Specific Heats and Specific Volumes of certain Alloys,**" in which he showed that the calculated and observed values in the cases examined agreed very closely.

Mr. FRANK FOSTER, B.Sc., read a paper entitled, "**On Phenomena due to Repetitions of Stress, and on a New Testing Machine.**"

General Meeting, February 2nd, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

Miss CATHERINE RADFORD, B.Sc., of Owens College, was elected an ordinary member of the Society.

Ordinary Meeting, February 2nd, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The following were among the recent donations to the Society's library:—"*Zelandia Illustrata.*" 3[e] Vervolg. By M. Fokker. (8vo., Middelburg, 1902), presented by the Zeeuwsch Genootschap der Wetenschappen; "*Pharmaceutical Society of Great Britain. The Museum Report*," by E. M. Holmes (8vo., London, 1903), presented by the Pharmaceutical Society; "*Codex Diplomaticus Lausatiæ Superioris, II.*"...Herausg. von R. Jecht, Bd. 2, Hft. 4, presented by the Oberlausitzische Gesellschaft der Wissenschaften.

The PRESIDENT informed the meeting that Dr. Wilde had presented to the Society a marble columnar pedestal on which to place the bust of Dr. Dalton, presented some time ago by Sir Henry E. Roscoe, and proposed that the best thanks of the Society be accorded to Dr. Wilde for his generous gift.

A resolution was adopted, proposed by Professor DIXON, that a letter of congratulation be sent to one of its Honorary Members, Professor D. Mendeléeff, whose 71st birthday was to be celebrated in St. Petersburg during the next week.

Mr. C. E. STROMEYER, M.Inst.C.E., exhibited an interesting photograph of a flash of lightning, taken at Johannesburg, in which two distinct parallel images were seen. These were produced by moving the camera quickly during the passage of the lightning.

Dr. CHARLES H. LEES exhibited a screen, made by Professor Wood, of Johns Hopkins University, America, for cutting off all but the ultra-violet rays; two film photographs (prepared by Miss C. Radford) of the spectrum of iron, one of which was taken without and the other with the opaque screen; and a cyanine prism for showing the phenomenon of anomalous dispersion.

Dr. LEES also showed a number of cloud photographs, which had been lent for the purpose, and included many varieties not usually available as lantern slides.

Mr. R. L. TAYLOR, F.C.S., F.I.C., called attention to the large quantities of arsenic existing in some, but not all, of the green wax tapers now on sale in the shops of Manchester; the source being undoubtedly the arsenite of copper used for imparting a green hue to the wax.

Mr. C. L. BARNES, M.A., referred to the communication made by Mr. Taylor at the meeting held on January 5th, 1904, and pointed out that a different method for obtaining hydrobromic acid free from bromine had long been known, a bromide of one of the alkaline-earth metals, instead of potassium bromide, being used as the source.

Dr. W. E. HOYLE, F.R.S.E., exhibited from the collection of the Manchester Museum nestlings of the following species of birds: Heron, Oyster-catcher, Water Rail, Lesser black-backed Gull, Herring Gull, Razor-bill, Cormorant, and Kite.

Mr. C. OLDHAM made some interesting observations upon these birds, more particularly on the Gulls and the Kite.

Mr. F. F. LAIDLAW, B.A., also exhibited some species of Oriental Dragon-flies, some of which were of interest more especially because of their geographical distribution.

Dr. HOYLE also communicated a paper entitled, "**A Diagnostic Key for the Genera of recent Dibranchiate Cephalopoda,**" which was intended to be of service to Curators of Museums and other naturalists and collectors, by enabling them to identify the genera of Cuttle-fish which may be under their charge.

Ordinary Meeting, February 16th, 1904.

CHARLES BAILEY, M.Sc., F.L.S., in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. H. E. SCHMITZ, M.A., B.Sc., and Mr. R. S. HUTTON, M.Sc., were nominated auditors of the Society's accounts for the Session 1903-1904.

Messrs. H. MORRIS-AIREY, M.Sc., and E. D. SPENCER read a paper (communicated by Dr. C. H. LEES) entitled "**On a**

suitable Arrangement for Determining the Capacities of Condensers by the Successive Discharge Method."

Dr. G. A. HEMSALECH read a paper (communicated by Dr. C. H. LEES) entitled "**On the Spectrum of the Glow Discharge at Atmospheric Pressure.**"

Special Meeting, February 22nd, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

Mr. F. SODDY, M.A., the Wilde Lecturer, gave an experimental demonstration of the properties of Radium.

After a brief reference to the manner in which the element was discovered by Mdme. Curie, he explained that it gave off three kinds of rays, of which by far the most important were the α rays, composed, probably, of particles of helium, these were about the size of an atom of hydrogen, and carried a positive charge of electricity. They had very little penetrative power, being stopped by a single sheet of paper, or even by a few inches of air; they moved with a velocity of about 20,000 miles a second, and were deviated, though very slightly, in a powerful magnetic field. The other two kinds were the β rays, identical with the cathode rays discovered long ago by Sir W. Crookes, and the γ rays which were analogous to the Röntgen rays, and had enormous penetrative power, an inch of solid steel not sufficing to prevent their escape.

Mr. Soddy also showed the almost instantaneous action of radium in discharging an electrified body, and the slower action of polonium, which gives off only α rays, in bringing about the same result.

He described the disintegration of radium as taking place in four stages, as though the atom had four explosive centres. The first disruption liberates the α rays, and leaves an emanation, itself not a permanent form of matter, but capable of again disintegrating and leaving a deposit on solid substances, whereby they acquire the power of induced radio-activity: the radio-activity of the latter shows that even here the final state was not reached.

The following highly interesting experiments were shown :—

I. A radio-graph, taken by M. Becquerel by the uranium rays with a fortnight's exposure, and a negative produced by writing on a photographic plate with a glass tube containing a few milligrams of pure radium bromide, were shown to illustrate the million-fold more intense activity of radium as compared with uranium.

II. The ionisation of the air by the radium rays was shown by their power of making collapse a silk tassel electrified by stroking with a rubber tobacco-pouch.

III. The α rays were illustrated by means of a preparation of polonium which gives only this type of radiation and no β and γ rays. The silk tassel was discharged by the bare preparation as in the case of radium, but a single sheet of paper was shown to completely stop the (α) rays of polonium while not appreciably affecting the (β and γ) rays of radium. The α rays of radium were shown by means of several of Sir William Crookes' spinthariscopes.

IV. The β rays of radium were illustrated by means of a screen of platino-cyanide of barium, which fluoresced a deep green colour when the radium was held behind, the rays passing through the opaque card and through copper foil without appreciable loss.

V. The γ rays of radium were shown passing through $\frac{3}{4}$ inch of steel, and plainly illuminating barium platino-cyanide on the other side.

VI. The deviation of the cathode-ray of the Crookes' tube by a magnet was first shown, and afterwards the deviation of the β ray of radium by a more powerful electro-magnet, the image on the screen being displaced when the current was applied.

VII. The heating of radium by the bombardment of its own (α) radiations was illustrated by an analogous experiment of raising a platinum plate to a white heat by 'focussing' on it a stream of cathode-rays inside a Crookes' tube.

VIII. The mechanical effect of the cathode-rays in driving a windmill was shown to anticipate the not yet discovered mechanical 'perpetuum mobile' worked by radium rays.

IX. By means of diagrams in which the radium atom was depicted as a shell charged with four separately and independently exploding charges the disintegration theory was illustrated. The emanation was represented as the residue of the original atom in which a charge had exploded and blown away fragments in the form of α rays; etc.

X. Some radium emanation obtained that morning by pumping off the gases from a closed radium solution was exhibited in a glass tube containing a piece of the mineral willemite (zinc silicate). The latter fluoresced brilliantly a beautiful green under the action of the rays from the emanation inside the tube. The radium from which this effect in the first instance is derived had been left in London. Afterward the same emanation was shown in a tube containing the mineral sparteite which fluoresces a ruddy orange or pink.

XI. The gaseous nature of the emanation of radium was shown by blowing air through a small quantity of a radium solution, which had been closed up for some time, then through a long tube on to the charged silk tassel which was instantaneously discharged.

XII. The condensation of the emanation at low temperatures was shown by blowing the emanation from the tube (Expt. X.) through a glass spiral immersed in liquid air, into a long tube containing a screen of phosphorescent zinc sulphide. The emanation was condensed in the spiral and none passed into the tube beyond. On removing the liquid air and gently blowing through the spiral into the tube beyond, the emanation was blown out as the spiral warmed up and made the zinc sulphide screen intensely bright. The passage of the light up the tube as the blowing was continued well showed the ordinary gaseous nature of the emanation.

XIII. The excited or induced activity from radium left behind where the emanation has been was shown by blowing the latter out of the zinc sulphide tube, when a considerable part of the luminosity remained.

XIV. The original spectrum tube in which helium was first observed in the gases from radium was exhibited.

XV. An apparatus designed by the Hon. J. R. Strutt to illustrate the charge carried away by the rays of radium was exhibited. A sealed glass tube containing a radium compound was supported by quartz inside a perfectly exhausted space, and to its lower end gold leaves were attached. The latter continuously received a charge, diverged until they touched the walls, and collapsed, going through a complete cycle every four minutes. The apparatus had been continuously working for several months, and constitutes a perpetual motion machine in its essential characteristics.

A hearty vote of thanks was passed to Mr. Soddy for his lecture.

Special Meeting, February 23rd, 1904.

Professor W. Boyd Dawkins, D.Sc., F.R.S., President, in the Chair.

The Wilde Lecture, "**On the Evolution of Matter as revealed by the Radio-active Elements,**" was delivered by Mr. F. Soddy, M.A., of University College, London.

Ordinary Meeting, March 1st, 1904.

Professor H. B. Dixon, M.A., F.R.S., in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Professor A. Schuster, Ph.D., F.R.S., read a paper, entitled "**On the Rate at which Ions are generated in the Atmosphere,**" in which he described a method of observation which allowed him to determine the number of ions which are constantly being formed in the atmosphere. All experiments which have hitherto been made only determined the total number of ions present but not the rate at which they recombined or formed. Some experiments made in a field near Rochdale on Sunday, February 28th, gave 2,400 for the number of ions in each cubic centimetre of air, and a formation of 18 new ones in each second, while on the roof of the Physical Laboratory at the Owens College on the Monday the numbers were 3,600 with a formation of 38 fresh ones each second.

General Meeting, March 15th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

Dr. ARNOLD W. LEA, of 252, Oxford Street, Manchester, was elected an ordinary member of the Society.

Ordinary Meeting, March 15th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

The PRESIDENT stated he had to announce, with great regret, the death of Mr. J. J. Ashworth, a member of the Society.

Mr. CHARLES BAILEY, M.Sc., F.L.S., spoke of the services the late Mr. Ashworth had rendered to the Society in his capacity of Hon. Treasurer, which office he held for a number of years.

Mr. J. COSMO MELVILL, M.A., F.L.S., exhibited from his Herbarium (*a*) a specimen of the *Tulip Tree,* from North America, with the following inscription on the label, in the handwriting of C. von Linné (Linnæus).—" LIRIODENDRON *tulipifera* Lin. Sp. Pl. I., p. 755 n. 1. Specimen debeo viro nobili Petro van de Poll." Other Linnean specimens are, besides this, to be found in the collection. (*b*) A sheet of *Sprengelia incarnata* Sm. Nat. Ord. *Epacrideæ*, from New South

Wales; being a co-type and part of the original gathering from which Sir James E. Smith's description was taken, vide *Sprengelia* in "Rees' Cyclopædia," 1819, where the following remarks occur:—

"Sprengelia, named by the writer of this article,* in honour "of Mr. Christian Conrad Sprengel, Master of a Grammar School "at Spandow, in Brandenburgh, who published at Berlin, in 1793, "a most ingenious work on the manner in which insects promote "the impregnation of plants. This fact is illustrated by several "hundred particular examples, accompanied by figures of each. "Dr. Curtius Sprengel, now Professor of Botany at Halle, may "also claim his share of botanical commemoration in the above "name."

The specimen now before us is thrice labelled, all in Sir J. E. Smith's handwriting, the principal and central one running as follows:—

"Sprengelia incarnata.
Given to Mr. Wilson.
— Lambert.
— Forster.

"Christian Conrad Sprengel, Master of a Grammar School at Spandow in Brandenburgh: Book published at Berlin, 1793."

The second ticket gives the name again, "*Sprengelia* "*incarnata*, Smith in Stockholm Transactions for 1794: "Monogynia. New South Wales."

The third, a descriptive label, is thus written:—

"Caps 5 loc. 5 valv.
"Dissep. e medio valvularum semina plurima subrotunda.
"Cal. 5. phyllus, persistens. Cir. rotata. Stam. 5, "antheris connatis. Syng. Monogamia. *Laid in.*"

This last specimen is only one of a large number of Australian plants in the collection, all being co-types with the examples in Smith's Herbarium at the Linnean Society's Rooms, Burlington House, Mr. B. Daydon Jackson having himself compared some of them, at my request.

*Sm. Tracts 272, f. 2 (1798). Sm. in *Vet. Acad. Handl. Stockholm*, 1794, 260.

Many of these specimens possess more or less full descriptions, and sometimes a generic or specific name proposed, then erased, and another substituted; specially is this the case with the genus *Tetratheca* Smith, and certain *Myrtaceæ.*

It is thought fitting that especial attention to these and other historical entities in this Herbarium should be drawn to-day (March 15th, 1904), since the greater portion of it has this morning been transferred to the care of the Manchester Museum, Owens College. It is hoped, as requested by the Authorities, that particulars may be given, in some detail, as to the component parts of the collection and set forth in the Annual Report of the Museum.

Mr. MELVILL also read a paper by Mr. RUPERT VALLENTIN, entitled, "**The Falkland Islands Re-visited,**" in which the principal zoological, botanical, and geological features of the district were vividly described. Lantern slides illustrating the habits of the penguin and other birds were also shown, besides a miscellaneous selection, principally of views in the Islands.

Mr. A. D. DARBISHIRE, B.A., gave an account of Mendel's Principles of Heredity which are causing much disturbance among biologists at the present time. His paper showed the close connection which existed between Mendel's theory and the problem of the origin of species as it is presented to Naturalists of to-day.

After describing Mendel's results Mr. DARBISHIRE referred to some hybridisation experiments, which he had made, by crossing the so-called Japanese waltzing mice with albinos, in order to test the validity of Mendel's theories.

Specimens of waltzing and albino mice as well as the resultant hybrid (which was hard to distinguish from a common house-mouse) were shown at the meeting.

The paper was concluded by the description of a method for explaining Mendel's theory in a simple manner by means of red and white counters.

Mr. D. L. CHAPMAN, M.A., described some experiments on the production of photo-chemically active chlorine. When in this condition, the gas unites with hydrogen, under the influence of light, much more readily than when inactive. The two varieties are not essentially distinct, but some presumably molecular difference exists between them to account for this anomalous behaviour, and it had been the aim of Mr. Chapman to discover a means of inducing the property or of causing it to disappear at will.

Ordinary Meeting, March 29th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. C. L. BARNES, M.A., quoted a passage from "The Natural History of Selborne," in which a sound as of a loud humming of bees is said to be audible on hot summer days "the whole common through, from the Money Dells to Mr. White's avenue gate," and this although not a single insect is in sight. The phenomenon has been observed in other quarters, notably on the Shoshone Lake, in the Yellowstone Park, where it appears to be peculiarly distinct. Reference was also made to the passage in "The Tempest" (Act. III., sc. ii.), beginning "The isle is full of noises, sounds, and sweet airs, which give delight and hurt not," and to "Comus," where the lady speaks of "airy tongues that syllable men's names On sands and shores and desert wildernesses."

Mr. R. C. PHILLIPS read a paper (communicated by Mr. C. W. SUTTON, M.A.) on **"Mean Tones, Equal Tempered Tones, and the Harmonic Tetrachords of Claudius Ptolemy."**

Dr. J. C. CAIN, M.Sc., read a paper (communicated by Professor H. B. DIXON, M.A., F.R.S.), entitled, **"The Constitution of the Ammonium Compounds."**

General Meeting, April 12th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The following resolutions, of which notice had previously been given, were carried unanimously:—

"That the Officers and Council for the next Session be balloted for *en bloc.*"

"That two scrutineers be appointed by the meeting, and that they examine the balloting papers whilst the ordinary business is being carried on, and report the result when ascertained."

Ordinary Meeting, April 12th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. FRANCIS JONES, M.Sc., F.R.S.E., read a paper entitled, **"On the Union of Hydrogen with Sulphur, Selenium, and Tellurium."**

ANNUAL GENERAL MEETING, APRIL 26TH, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The Annual Report of the Council and the Statement of Accounts were presented, and it was resolved:—"That the Annual Report, together with the Statement of Accounts, be adopted, and that they be printed in the Society's *Proceedings.*"

In accordance with the resolutions adopted at a General Meeting held on April 12th, the Officers and Council were balloted for *en bloc,* and Mr. CHARLES OLDHAM and Mr. CHARLES LEIGH were appointed Scrutineers of the balloting papers.

The following members were elected officers of the Society and members of the Council for the ensuing year :—

President: W. BOYD DAWKINS, M.A., D.Sc., F.R.S.

Vice-Presidents: Sir WILLIAM H. BAILEY; H. B. DIXON, M.A., F.R.S.; CHARLES BAILEY, M.Sc., F.L.S.; HORACE LAMB, M.A., LL.D., F.R.S.

Secretaries: FRANCIS JONES, M.Sc., F.R.S.E., F.C.S.; CHARLES H. LEES, D.Sc.

Treasurer: ARTHUR McDOUGALL, B.Sc.

Librarian: W. E. HOYLE, M.A., D.Sc., F.R.S.E.

Other Members of the Council: FRANCIS NICHOLSON, F.Z.S.; F. E. WEISS, D.Sc., F.L.S.; C. E. STROMEYER, M.Inst.C.E.; FRANK SOUTHERN, B.Sc.; WILLIAM THOMSON, F.R.S.E., F.C.S.; THOMAS THORP, F.R.A.S.

Ordinary Meeting, April 26th, 1904.

Professor W. BOYD DAWKINS, D.Sc., F.R.S., President, in the Chair.

The thanks of the members were voted to the donors of the books upon the table. The following were among the recent accessions to the Society's Library :—"*De Tjandi Mĕndoet voor de Restauratie,*" door B. Kersjes en C. den Hamer (fol., Batavia, 1903), and "*De Java-oorlog van 1825-30*"...Derde Deel, door P. J. F. Louw (4to., Batavia, 1904), presented by the Bataviaasch Genootschap van Kunsten en Wetenschappen; "*A Dream of Worlds beyond us,*" by A. Welcker (8vo., San Francisco, 1903), presented by the author; "*Report of the Select Committee on Ventilation*" (8vo., London, 1904); "*Flora Capensis,*" vol. iv.

sect. ii. By Sir. W. T. Thiselton-Dyer. (8vo., London, 1904), purchased; "*Handy Guide to the [Manchester] Museum.*" By W. E. Hoyle. 3rd ed. (8vo., Manchester, 1903), presented by the Museum; "*The Rise and Progress of the Standard Oil Company.*" By G. H. Montague (8vo., New York, 1904), presented by Messrs. Harper Bros.; "*Free Trade versus Fair Trade.*" By Lord Farrer. New ed. (8vo., London, 1904), presented by the Dowager Lady Farrer; "*Altitudes in the Dominion of Canada.*" With profiles. By James White (8vo., Ottawa, 1901), presented by the Geological Survey of Canada; "*Sketches of the .... Honorary Medical Staff of the Manchester Infirmary.*" By E. M. Brockbank (4to., Manchester, 1904), presented by the author.

The PRESIDENT read the reply of Sir Henry E. Roscoe to the Society's address, presented at the function held in his honour at Owens College on April 22nd, 1904.

Mr. C. L. BARNES presented to the Society's Library Dr. F. W. Jordan's biography of Dr. Joseph Jordan, formerly a member of the Society, and a contemporary and associate of Dalton before the foundation of the Manchester Medical School.

Mr. F. A. BRUTON, M.A., read a paper entitled, "**Note on the Eye of the Mole,**" and exhibited some specimens of the fœtus in which the eye was clearly shown, and also the remarkable development of the snout, the ear processes (which are very large in the adult), and the powerful hand which is used for burrowing.

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., read a paper entitled, "**On the Presence of Arsenic in the Body and its Secretion by the Kidneys.**"

The PRESIDENT read a paper entitled, "**On the Discovery of *Elephas antiquus* at Blackpool,**" and exhibited a tooth of one of the rarer species of extinct elephants.

A paper by Mr. J. G. ISHERWOOD, B.Sc., entitled, "**Tables of the Bessel Functions for Pure Imaginary Values of the Argument,**" was communicated by Dr. C. H. LEES.

Annual Report of the Council, April, 1904.

The Society began the session with an ordinary membership of 157. During the present session 21 new members have joined the Society; 10 resignations have been received, and the deaths have been 6, *viz.*: Mr. J. J. ASHWORTH, Mr. JAMES EDWARD CORNISH, Mr. EDWARD COWARD, Mr. WILLIAM GOLDTHORPE, Mr. THOMAS HARKER and Mr. THOMAS READ WILKINSON, whilst 3 members have been removed from the list for non-payment of their subscriptions. This leaves on the roll 159 ordinary members. The Society has also lost 3 honorary members by death, *viz.*: Professor J. WILLARD GIBBS, For.Mem.R.S., of Yale University, U.S.A., the Rev. Dr. GEORGE SALMON, F.R.S., Provost of Trinity College, Dublin, and Professor CARL ALFRED VON ZITTEL, of Munich. Memorial notices of these gentlemen appear at the end of this report.

The Treasurer reports a decided improvement in the finances, due to the general efforts made during the last three years to increase the membership; but the unusual number of resignations received during the current session, and the needs of the Society still call for sustained exertion in the same direction.

The Society commenced the session with a total balance of £304. 14s. 2d., from all sources, this amount being made up of the following balances:—

	£	s.	d.
At the credit of General Fund	£143	0	5
„ „ Wilde Endowment Fund...	127	17	1
„ „ Joule Memorial Fund......	49	5	10
„ „ Dalton Tomb Fund	32	14	8
	£352	18	0
Less the amount standing at the debit of the Natural History Fund...............	48	3	10
	£304	14	2

The total balance at the close of the session amounted to £369. 10s. 5d., and the amounts standing at the credit of the separate accounts, on the 31st March, 1904, are the following:—

		£	s.	d.
At the credit of General Fund	....	£97	13	1
,, ,,	Wilde Endowment Fund...	181	4	8
,, ,,	Joule Memorial Fund......	57	2	0
,, ,,	Dalton Tomb Fund.........	33	10	8
Cash in hand 31st March, 1904	....	£369	10	5

The Wilde Endowment Fund, which is kept as a separate banking account, shows a balance of £181. 4s. 8d. in its favour, as against £127. 17s. 1d., at the beginning of the financial year. The receipts from the invested funds are slightly more than last year, and your Council sees no reason to make any change in its investments.

It will be observed that the long-continuing adverse balance of the Natural History Fund has been eliminated in this year's annual statement of accounts, by not passing to its debit, as usual, the current payments made during the session for Natural History publications, viz., £43. 10s. 0d., and Natural History plates, £9. 12s. 6d. Of these amounts only £13. 11s. 4d. has been charged to this account, and the balance, £39. 11s. 2d. appears in the general account of the Society.

No expenditure has been incurred in respect to the Joule Memorial Fund and the Dalton Tomb Fund, the balances of which remain at the amounts stated above. The Dalton Tomb Fund stands as a separate account at the Manchester and Salford Savings Bank.

The Librarian reports that during the session 610 volumes have been stamped, catalogued and pressmarked, 580 of these being serials, and 30 separate works. There have been written 204 catalogue cards, 142 for serials, and 62 for separate works. The total number of volumes catalogued to date is 27,539 for which 9,127 cards have been written.

Satisfactory use is made of the library for reference purposes, but the number of volumes consulted is not recorded. During the session, 184 volumes have been borrowed from the library, as compared with 163 in the previous session.

Some attention has continued to be paid to the completion of sets, 11 parts having been obtained which partly complete two sets. These parts were presented by the respective societies publishing them.

Comparatively little binding has been done this session, 148 volumes having been bound in 133.

A record of the accessions to the library shows that, from April, 1903, to March, 1904, 687 serials and 55 separate works were received, a total of 742 volumes. The donations during the session (exclusive of the usual exchanges) amount to 50 volumes and 321 dissertations; 41 volumes of the *Archiv für Naturgeschichte* have been purchased (in addition to the periodicals on the regular subscription list).

During the past session the Society has arranged to exchange publications with the following:—The Dorset Natural History and Antiquarian Field Club; University of Montana; Cornell University.—The Journal of Physical Chemistry.

The publication of the *Memoirs and Proceedings* has been continued under the supervision of the Editorial Committee.

The Society is indebted to the following gentlemen for the undermentioned gifts:—

Sir Henry E. Roscoe, F.R.S., for a bronze bust of Dr. John Dalton.

Mr. R. D. Darbishire, for a complete set of the Society's *Memoirs and Proceedings.*

Mr. A. McDougall for a silhouette portrait of Dr. John Dalton.

Mr. Charles Leigh for a framed engraved portrait of Dr. John Dalton.

Dr. Henry Wilde, F.R.S., for a marble columnar pedestal on which to place the bust of Dalton.

The following letter was addressed to Professor D. Mendeléeff, of St. Petersburg, on his completing, in February last, his seventieth year:—

[COPY.]

February 9th, 1904.

On behalf of the members of the Manchester Literary and Philosophical Society, we beg to send you our most sincere congratulations on the occasion of the celebration of your 70th birthday.

In this House, where Dalton worked, and where he announced his Atomic Theory, your brilliant correlation of the Atomic Weights will always be honoured among the richest fruit that has sprung from Dalton's hypothesis. Your work has inspired Chemistry with a new life: there is no department of Physical Science which has not been fertilised and invigorated by your ideas.

We have the honour to be,

Your obedient servants,

(Signed) W. BOYD DAWKINS, *President.*

FRANCIS JONES,
CHARLES H. LEES. } *Hon. Secretaries.*

In reply to the above, the President received the following letter from Professor D. Mendeléeff:—

[COPY.]

$\frac{10}{23}$ *February, 1904.*

ST. PETERSBOURG.

DEAR SIR,

I beg you to accept and convey to the members of the Manchester Literary and Philosophical Society my heartiest thanks for the kind congratulations to my 70th birthday.

As a sincere lover of Dalton's genius, it is to me specially pleasant to hear from Dalton's followers that my work has been connected with the principles of his most fruitful ideas, which I have really taken up to such extent, that I hope to die always keeping at them without being disturbed by the new trials to destroy Dalton's theory. But all these trials, by my mind, are based upon a mixed-up conception of matter, energy and soul.

Yours very truly,

D. MENDELÉEFF.

The Council arranged for the Wilde Lecture to be delivered on Tuesday, February 23rd, 1904, by Mr. F. Soddy, M.A., of University College, London.

The Council resolved that an address be presented to Sir Henry E. Roscoe on the celebration of the jubilee of his taking his Doctor's Degree at Heidelberg. The following is a copy of the address presented at the Owens College on April 22nd, 1904:

[COPY.]

To Sir HENRY ENFIELD ROSCOE, LL.D., D.C.L., F.R.S.

The President, Council, and Members of the Manchester Literary and Philosophical Society desire to convey to you their heartiest congratulations on the celebration of the Jubilee of your Doctorate.

Elected into this Society in 1858, you performed the arduous duties of Secretary for twelve years with a zeal and unfailing courtesy which will always be remembered by us with sincere gratitude. For twelve years also you held the office of President or Vice-President, and most worthily upheld the dignity and scientific prestige of the Society.

Your eminence as a scientific man and the distinguished services you have rendered to this Society were recognized in 1900 by the award to you of the Dalton Medal, the highest honour we can bestow upon a member.

While we feel it unnecessary to detail your many contributions to Science, we wish to mention the debt that the historian of Chemistry and our Society owe to your work in elucidating from Dalton's manuscripts the genesis of the idea of the Atomic Theory.

(Signed) W. BOYD DAWKINS, *President*,
FRANCIS JONES, } *Hon. Secretaries.*
CHARLES H. LEES. }

April, 1904.

The following is the reply of Sir Henry E. Roscoe to the above address :—

THE LITERARY AND PHILOSOPHICAL SOCIETY OF MANCHESTER.

That the Council of the Literary and Philosophical Society has remembered this occasion is gratifying to me, holding as I do in pleasant memory my old association with its members.

Long may the oldest of provincial Scientific Societies flourish and renew its youth, proud of its association with the two great master minds, Dalton and Joule.

April 22nd, 1904. HENRY E. ROSCOE.

By the death of our honorary member, Prof. WILLARD GIBBS, of New Haven, the world of Science has lost not only one of the most distinguished among mathematicians, but one of that rarer band whose mathematic analysis has profoundly influenced the progress of physics and chemistry.

In his great memoir "On the Equilibrium of Heterogeneous Substances," published in 1876-78, he systematised the application of the second law of thermodynamics to the relations between chemical, electrical, and thermal energy and capacity for external work. Gibbs showed in this memoir how the experimental values for the density of nitrogen peroxide obtained by different observers could be interpreted quantitatively by the aid of his fundamental gas equation; and it fell to the lot of the writer, in 1899, to show how Gibbs' equation accounted for the densities observed when nitrogen peroxide was diluted with indifferent gases, and thus to demonstrate that nitrogen peroxide was capable of uniting with nitric oxide to form an unstable *gaseous* nitrogen trioxide. This is only one illustration of the aid which chemists derive from Gibbs' work.

The "Phase-Rule," developed theoretically by Gibbs, is now regarded by the great majority of chemists as governing the general state of complete heterogeneous equilibrium, and its application has been verified in the most varied cases of reversible chemical action. Professor Ostwald wrote, in 1892: "The importance of the thermodynamic papers of Willard Gibbs "can be best indicated by the fact that in them is contained, "partly explicitly, partly implicitly, a large part of the discoveries "which have since been made by various experimenters in the "domain of chemical and physical equilibrium."

Prof. Gibbs was born at New Haven in 1839. After graduating at Yale, and studying at Paris, Heidelberg, and Berlin, he was elected Professor of Mathematical Physics in Yale, in 1871. He was elected an honorary member of this Society in 1892, and received the Copley Medal of the Royal Society in 1901. He died April 28, 1903. H. B. D.

George Salmon was born in Dublin in 1819. He was educated at Trinity College, and after a brilliant University career was elected to a Fellowship in 1841. In his subsequent life it was his lot to attain to the highest distinction in widely different fields. For twenty years he held the post of Tutor, and although it is probable that the theological studies which afterwards became his predilection already absorbed much of his attention, his main outward activity during this period was in subjects of Pure Mathematics, and especially in Analytical Geometry. He was in constant and sympathetic correspondence with Sylvester and Cayley, and although somewhat careless about original publication himself, made many notable contributions to the branches of mathematics which were at that time in process of development. He is still more widely known on account of the unique excellence of his set treatises on Analytical Geometry. As systematic expositions of the actual state of the science, in which enthusiasm for what is new is tempered by a due respect for what is old, they stand almost unrivalled. Whether in the originals, or in the form of translations, they are still quoted as classics in every University of the world.

The estimate in which his mathematical work was held is further indicated by the numerous honours of a scientific kind which were subsequently bestowed upon him; he was elected a Fellow of the Royal Society in 1863, and received a Royal Medal in 1868 and the Copley Medal in 1889. He was also a member of the Institute of France, and of the Academies of Berlin and Göttingen.

His mathematical career, brilliant and unique in some ways as it was, came, however, to an end by his own choice in the year 1866, when he accepted the Regius Professorship of Divinity in Trinity College. He afterwards took a prominent part in the reorganization of the Church of Ireland which became necessary on the passing of the Disestablishment Act of 1869. On the death of Jellett, in 1888, he became, with universal approval, Provost of Trinity College, and proved most zealous and active in the administration of that great corporation.

In the opinion of competent judges, the ability which he showed in these various new directions was quite on a par with that which had brought him distinction as a pure mathematician. Indeed, if his mathematical achievements could be forgotten, he would still have left a great name as a theologian and as an administrator. Personally he was a striking figure, full of grace and dignity and energy, even to the last. He died on January 22nd, 1904.

H. L.

In the death of CARL ALFRED VON ZITTEL, who died on January 5th, 1904, the Society has lost an honorary member of the highest distinction. He was elected in 1895. Born in Baden in 1839, Zittel studied natural science in Heidelberg, and more especially geology and paleontology. After taking his doctor's degree, he studied the rich fossil treasures of France, and attended the lectures of the eminent tertiary paleontologist, Hébert. In 1861 he became *privat docent* in the University of Vienna, and was appointed to the position of assistant in the Natural History Museum of that city. At the age of 24 he accepted the professorship of Mineralogy, Geognosy, and Paleontology at the Polytechnicum of Karlsruhe. In 1866 he succeeded Oppel in the chair of Paleontology in the University of Munich, and in 1899 his high scientific position was recognised by his being chosen to replace Pettenkofer as President of the Bavarian Academy of Sciences. It was in Munich that the main work of his life was carried on.

There he organised the museum so that it became one of the best in Germany, and there he published the large number of works which have landed him in the first rank of Paleontologists. He was one of the few who had knowledge of both the recent and fossil forms, and who could bring to bear upon the study of a fossil group the results of original research in the analogous living types. His *opus magnum*, the *Handbuch der Paleontologie*, which came out in five volumes between 1876 and 1893, was written with a knowledge that made it the book of reference of the day by paleontologists. It is now the only complete work of the kind. It has been translated into English and French. This was followed in 1899 by a connected work on the progress of geology down to the end of the 19th century. The *Geschichte der Geologie und Paleontologie*, in which he records our advance in the knowledge of the ancient history of the earth, with a literary skill leaving nothing to be desired. This of itself would mark him out as one of the leaders of thought in his time. In October last his labours were cut short by his being knocked down in the street by a cycle, and the shock proved too severe for a frame weakened by heart disease. He died on the 5th January last, full of honours, amid the regret of his wide circle of friends, and of those who have been influenced by his writings in all parts of the civilised world.

W. B. D.

MR. JOHN JACKSON ASHWORTH was the son of a cotton manufacturer, Mr. Thomas Ashworth of the Pendleton Mills, and Gorsefield, Eccles Old Road, who was an Alderman of the Borough of Salford. Subsequently the son also became a member of the Salford Town Council. Mr. John Ashworth's tastes were from boyhood scientific, and in early life he became a student in the chemical laboratory of the old Owens College, then located in Quay Street, Manchester, a fellow student being the present Professor T. E. Thorpe, F.R.S., of the Government Laboratory in Clements' Inn Passage, London, and an honorary member of this Society. The sudden death of his father compelled young Ashworth, as the eldest son, to abandon his scientific career in order to carry on the mill and administer the estate under the provisions of his father's will for the benefit of the younger members of the family. He had a chequered business career owing to recurring depression in the cotton trade, but found much relief in his interest in pure science, especially chemical science. He gave much attention to microscopical investigation, practised photography very successfully, and, like his friend the late Mr. Richard Dale, the chemist, was fond of musical studies. He was elected a member of the

Manchester Literary and Philosophical Society on October 31st, 1871, but, owing to the increasing worries of business, he ceased to be a member a few years later. He subsequently rejoined the Society, being again elected a member on November 16th, 1887, and in the following year he again evinced his liking for scientific circles by becoming a life member of the British Association for the Advancement of Science at the Bath meeting of that year. In 1896 he was elected treasurer of the Manchester Literary and Philosophical Society, and continued to hold that office until his retirement in 1902. There is no doubt that these practical engagements with science, as being to some extent a fulfilment of his youthful desires, added much to the happiness of his later years. He was a man of genial temperament and generous impulses. He died at his residence at Didsbury on March 10th, 1904, in the 61st year of his age, and was buried at Willow Grove Cemetery, Reddish.

F. J. F.

James Edward Cornish, son of Samuel Cornish, second-hand bookseller, was born in New Turnstile, Holborn, in 1831. He was educated at the City of London School under Dr. Mortimer, and at the age of thirteen left school and was sent to the shop at Birmingham (still carried on under the style of Cornish Brothers) where his eldest brother William managed the business for himself and his brothers Charles, John, James, and Thomas, as they came of age. In 1854 James and his younger brother Thomas left their brothers and commenced at 33, Piccadilly, Manchester, and in a very few years took a leading position there. The partnership between them was dissolved in 1860, when Thomas opened a shop in Oxford Street, London. He died in 1880. James was appointed in 1868 bookseller to the Owens College, Victoria University, and he published many books by professors and lecturers at the College. In 1879 he purchased from Mr. Edwin Slater the old-established business at No. 16, St. Ann's Square, formerly carried on by Messrs. Simms and Dinham. This shop was much enlarged by

Mr. Cornish, and on the expiration of his lease at 33, Piccadilly, he in 1890 transferred the whole of his business to St. Ann's Square. Mr. Cornish had a large collection of valuable manuscripts and rare books, the greater part of which were bequeathed to him by his uncle Mr. Thomas Kerslake, of Bristol, who died in January, 1891. On the issue of his second-hand catalogues of this collection the bibliographical world were to some extent startled by the number of unique and rare items. One of these catalogues so surprised that astute bibliophile the late Mr. Henry Bradshaw, of Cambridge, that on its receipt he, along with Mr. Francis Jenkinson the present librarian of the University Library, Cambridge, immediately set off for Manchester, and they and the writer spent nearly the whole of two days going over the stock, and as the result of this visit many rare items were sent to Cambridge. The British Museum, the Bodleian Library, Oxford, and the Royal Library, Berlin, were also enriched by purchases from this collection.

Mr. Cornish died at his residence, Stone House, Alderley Edge, on Tuesday, December 15th, 1903, at the age of 72 years. Personally, he was an exceedingly quiet and retiring man, and took absolutely no part in public affairs. His business and his rural surroundings at home occupied the whole of his bachelor life. He will be much missed by a large circle of literary friends.

C. H. B.

EDWARD COWARD was born at Stand on April 26th, 1832. Educated at the Owens College, Manchester, he succeeded, on January 1st, 1852, his father in partnership in the firm of "Melland and Coward," at Heaton Mersey and Ardwick. The firm afterwards became merged in the Bleachers' Combine. Mr. Coward was at different times chairman of the Heaton Norris Local Board, the Lancashire Insurance Company until its absorption by the Royal Company of which latter he became a director, and the Ebbw Vale Iron Company. He was also a director of the Great Northern and the West Somerset Railway Companies. He was a man of culture and wide knowledge and greatly esteemed in all circles in which he moved. In 1874 he was elected a Member of the Iron and Steel Institute, in 1875 of the Institute of Mechanical Engineers, and in 1890 he became an Associate of the Institute of Civil Engineers. He was elected a member of this Society on January 25th, 1859. His death took place at Bournemouth on April 10th, 1904, in his 73rd year. E. M. C.

William Goldthorpe was born at Stockport on May 2nd, 1839. Educated at the Stockport Grammar School, and having acquired some commercial knowledge in the office of his father, John Goldthorpe, of that town, he studied medicine for a time at the Pine Street and Chatham Street Medical Schools, Manchester. Subsequently entering the legal profession, he was "called" in 1867, and commenced practice forthwith on the Northern Circuit. Having acted frequently as Deputy Judge of the County Court he followed Mr. John Addison as Chairman of the Salford Hundred Quarter Sessions in 1896. He died on March 8th, 1904, at his residence, Brook House, Burnage Lane, Levenshulme. A man of many interests and attainments, William Goldthorpe was perhaps best known for his musical accomplishments; not only a skilful organist—it is recorded that at the age of 8 he was called upon to play at the Tiviot Dale Wesleyan Chapel—he was also a thorough student of the history and theory of music, and occupied many important posts in the musical world, notably that of honorary organist to St. Peter's Church, Manchester, and more recently that of conductor of the Stockport Open Air Musical Festival. He was essentially a sociable man, and besides being a member of the Manchester Literary and Philosophical Society was connected with many other Societies and Clubs in this city, whilst his name was frequently prominent in philanthropic works. Above all he was ortunate in the possession of an unusually attractive personality; active and vigorous in mind and body, cheerful and kindly in disposition, firm but gentle in manner, having a well-stored memory and aptness of speech, he gathered round him a wide circle of friends, and was much respected and beloved of them. He married in July 1886 Mrs. Watts, widow of the late Samuel Watts of Burnage Hall and of the firm of S. and J. Watts and Co. of this city. F. S.

THOMAS HARKER was born at Hawes, a small market town in Wensleydale, Yorkshire, in 1830. His father, for the sake of his large family, wisely resolved to remove to Manchester, where he settled in 1844. After a short experience in a stock-broker's office, he entered, in 1849, the service of Messrs. Rylands and Sons, where his brother-in-law was a buyer. He maintained his connection with this firm as salesman, buyer, and director until a few months before his death.

In early life, fishing was his favourite amusement, and his devotion to the "gentle craft" continued till late on in life. As a member of the "Anglers' Club" he helped to make known to his fellow members the waters of his native dales. In later life he made flower-growing one of his hobbies, and was a very successful exhibitor at local shows. In politics he was an advanced Liberal, and for many years was a well known figure at the Manchester Reform Club.

About twelve years before his death he was made a magistrate, but of late years, owing to failing health, seldom appeared on the bench. W. H. R.

THOMAS READ WILKINSON was born in Duke Street, Chorlton-on-Medlock, on March 13th, 1826. His father, Thomas Wilkinson, was a printer, and the founder of the now well-known Gutenberg Printing Works, of Pendleton. At the age of 13 the boy entered his father's printing works as a compositor. He remained at this work two years, from 1839 to 1841. In the latter year he entered the Manchester and Salford Bank as a clerk, thus beginning a connection which lasted uninterruptedly until his death, 62 years later, in 1903. Mr. Wilkinson rose steadily in the Bank, becoming General

Manager in 1875, on the retirement of Mr. William Langton, between whom and Mr. Wilkinson a very warm friendship existed. Banking was by no means Mr. Wilkinson's only interest, however. He was a keen politician, an omnivorous reader of the best books, an enthusiastic lover of art and of the stage, and in his holidays, an indefatigable traveller. All forms of healthy human activity aroused his interest and sympathy, and, in conversation with him, one was continually reminded of Terence's "Nihil humani a me alienum puto." Mr. Wilkinson was elected a member of the Society in 1859. In 1861 he read a paper before the Society on "The Traffic in Intoxicating Drinks." He was an active member of the Manchester Statistical and Geographical Societies. In 1891, after fifty years of service, he resigned his position as General Manager of the Manchester and Salford Bank, and was made a director. In 1895 he moved from Manchester to Knutsford, where he lived for eight years, coming regularly into Manchester and retaining always a keen interest in the social and business life of the city. He died at Knutsford on June 11th, 1903, after a short illness.

F. S. A.

NOTE.—The Treasurer's Accounts of the Session 1903-1904, of which the following pages are summaries, have been endorsed as follows:

April 25th, 1904. Audited and found correct.

We have also seen, at this date, the certificates of the following Stocks held in the name of the Society:—£1,225 Great Western Railway Company 5% Consolidated Preference Stock, Nos. 12,293, 12,294, and 12,323; £258 Twenty years' loan to the Manchester Corporation, redeemable 25th March, 1914 (No. 1564); £7,500 Gas Light and Coke Company Ordinary Stock (No. 6,389); and the deeds of the Natural History Fund, of the Wilde Endowment Fund, those conveying the land on which the Society's premises stand, and the Declaration of Trust.

Leases and Conveyance dated as follow:—

22nd Sept., 1797.
23rd Sept., 1797.
25th Dec., 1799.
" " "
22nd Dec., 1820.
23rd Dec., 1820.

Declarations of Trust:—

8th Jan., 1878.
24th June, 1801.
23rd Dec., 1820.
30th Apr., 1851.

We have also verified the balances of the various accounts with the bankers' pass books.

(Signed) H. E. SCHMITZ.
R. S. HUTTON.

MANCHESTER LITERARY AND

Dr. *Arthur McDougall, Treasurer, in Account with the*

	£ s. d.	£ s. d.
To Cash in hand, 1st April, 1903		144 2 5
To Members' Subscriptions :—		
Half Subscriptions, 1899-00, 1 at £1 1s. 0d.	1 1 0	
,, ,, 1900-01, 1 ,, ,,	1 1 0	
,, ,, 1902-03, 3 ,, ,,	3 3 0	
,, ,, 1903-04, 13 ,, ,,	13 13 0	
Subscriptions :— 1900-01, 2 ,, £2, 2s. 0d.	4 4 0	
,, 1901-02, 2 ,, ,,	4 4 0	
,, 1902-03, 14 ,, ,,	29 8 0	
,, 1903-04, 121 ,, ,,	254 2 0	
,, 1904-05, 2 ,, ,,	4 4 0	
		315 0 0
To Transfers from the Wilde Endowment Fund		81 10 0
To Sale of Publications		12 1 8
To Dividends :—		
Natural History Fund	58 3 9	
Joule Memorial Fund	7 7 10	
		65 11 7
To Income Tax Refunded :—		
Natural History Fund	3 11 5	
Joule Memorial Fund	0 8 4	
		3 19 9
To H. Sidebottom for plates		0 10 0
To Discount on Knowles' bill		0 1 0
To return of excess of subs. to Zoological Society		0 1 0
		£622 17 5

NATURAL HISTORY

	£ s. d.
To Dividends on £1,225 Great Western Railway Company's Stock	58 3 9
To Remission of Income Tax 1903	3 11 5
	£61 15 2

JOULE MEMORIAL

	£ s. d.
To Balance, 1st April 1903	49 5 10
To Dividends on £258 Loan to Manchester Corporation	7 7 10
To Remission of Income Tax, 1903	0 8 4
	£57 2 0

WILDE ENDOWMENT

	£ s. d.
To Balance 1st April, 1903	127 17 1
To Dividends on £7,500 Gas Light and Coke Company's Ordinary Stock	313 10 0
To Remission of Income Tax, 1903	19 5 0
To Bank Interest	2 4 5
	£462 16 6

DALTON TOMB

	£ s. d.
To Balance, 1st April, 1903	32 14 8
To Bank Interest	0 16 0
	£33 10 8

PHILOSOPHICAL SOCIETY.

Society, from 1st April, 1903, to 31st March, 1904. **Cr.**

	£ s. d.	£ s. d.
By Charges on Property :—		
Chief Rent (Income Tax deducted) ..	12 5 5	
Income Tax on Chief Rent ..	0 11 10	
Insurance against Fire ..	13 17 6	
		26 14 9
By House Expenditure :—		
Coals, Gas, Electric Light, Water, Wood, &c. ..	29 7 3	
Tea, Coffee, &c., at Meetings ..	25 1 0	
Cleaning, Sweeping Chimneys, &c. ..	2 13 2	
Reseating Chairs ..	3 0 0	
		60 1 5
By Administrative Charges :—		
Housekeeper ..	59 16 0	
Postages, and Carriage of Parcels and of "Memoirs" ..	39 10 3½	
Stationery, Cheques, Receipts, and Engrossing ..	12 18 2½	
Printing Circulars, Reports, &c. ..	19 18 4	
Miscellaneous Expenses ..	7 0 3	
		139 3 1
By Subscriptions returned ..	..	2 2 0
By Publishing :—		
Printing "Memoirs and Proceedings" (Vol. 47, pt. 3, to Vol. 48, pt. 1) ..	111 15 8	
Illustrations for "Memoirs" ..	21 1 0	
Binding "Memoirs" ..	2 0 0	
		134 16 8
By Library :—		
Books and Periodicals (except those charged to Natural History Fund) ..	84 13 1	
Periodicals formerly subscribed for by the Microscopica and Natural History Section ..	7 0 0	
		91 13 1
By Natural History Fund :—		
(Items shown in the Balance Sheet of this Fund below) ..	..	13 11 4
By Joule Memorial Fund :—		
(No Expenditure this Session) ..		0 0 0
By Balance at Williams Deacon's Bank, 1st April, 1904 ..	144 15 1	
,, ,, in Treasurer's hands ..	10 0 0	
		154 15 1
		£622 17 5

FUND, 1903—1904. (Included in the General Account, above.)

	£ s. d.
By Balance against, 1st April, 1903 ..	48 3 10
By Natural History Books and Periodicals ..	13 11 4
(No Balance)	
	£61 15 2

FUND, 1903—1904. (Included in the General Account, above.)

	£ s. d.
(No expenditure this Session).	
By Balance, 1st April, 1904 ..	57 2 0
	£57 2 0

FUND, 1903—1904.

	£ s. d.
By Assistant Secretary's Salary, April, 1903, to March, 1904 ..	117 10 0
By Maintenance of Society's Library :—	
Binding and Repairing Books ..	18 2 1
By Decorating and Repairs to Society's Premises ..	3 16 9
By Gold Medal and Engraving same ..	19 3 0
By Honorarium to Lecturer, 1903 ..	15 15 0
,, ,, ,, 1904 ..	15 15 0
By Cleaning Pictures ..	10 0 0
By Transfers to Society's Funds ..	81 10 0
By Balance at District Bank, 1st April, 1904 ..	181 4 8
	£462 16 6

FUND, 1903-1904.

	£ s. d.
(No Expenditure this Session).	
By Balance at Manchester and Salford Savings Bank, 1st April, 1904 ..	33 10 8
	£33 10 8

THE COUNCIL
AND MEMBERS
OF THE
MANCHESTER
LITERARY AND PHILOSOPHICAL SOCIETY.

(CORRECTED TO JULY 12TH, 1904.)

President.
W. BOYD DAWKINS, M.A., D.Sc., F.R.S.

Vice-Presidents.
SIR WILLIAM H. BAILEY, M.I.Mech.E.
H. B. DIXON, M.A., F.R.S., F.C.S.
CHARLES BAILEY, M.Sc., F.L.S.
HORACE LAMB, M.A., LL.D., D.Sc., F.R.S.

Secretaries.
FRANCIS JONES, M.Sc., F.R.S.E., F.C.S.
CHARLES H. LEES, D.Sc.

Treasurer.
ARTHUR McDOUGALL, B.Sc.

Librarian.
W. E. HOYLE, M.A., D.Sc., F.R.S.E.

Other Members of the Council.
FRANCIS NICHOLSON, F.Z.S.
F. E. WEISS, D.Sc., F.L.S.
C. E. STROMEYER, M.Inst.C.E.
FRANK SOUTHERN, B.Sc.
WILLIAM THOMSON, F.R.S.E., F.C.S.
THOMAS THORP, F.R.A.S.

Assistant Secretary and Librarian.
A. P. HUNT, B.A.

ORDINARY MEMBERS.

Date of Election.

1901, Dec. 10. Adamson, Harold. *Oaklands, Godley, near Manchester.*

1902, Mar. 18. Allen, J. Fenwick. 147, *Withington Road, Whalley Range, Manchester.*

1902, Jan. 21. Allott, Charles S., M.Inst.C.E. 519, *Stretford Road, Old Trafford, Manchester.*

1870, Dec. 13. Angell, John, F.C.S., F.I.C. 6, *Beaconsfield, Derby Road, Withington, Manchester.*

1896, Jan. 31. Armstrong, Frank. 88 & 90, *Deansgate, Manchester.*

1895, Jan. 8. Armstrong, George B. *Clarendon, Sale, Cheshire.*

1865, Nov. 14. Bailey, Charles, M.Sc., F.L.S. *Atherstone House, North Drive, St. Annes-on-the-Sea, Lancs.*

1888, Feb. 7. Bailey, Alderman Sir William H. *Sale Hall, Sale, Cheshire.*

1895, Jan. 8. Barnes, Charles L., M.A. 8, *Swinton Avenue, Chorlton-on-Medlock, Manchester.*

1903, Oct. 20. Barnes, Jonathan, F.G.S. *South Cliff House*, 301, *St. Clouds Street, Higher Broughton, Manchester.*

1896, April 14. Behrens, George B. *The Acorns*, 4, *Oak Drive, Fallowfield, Manchester.*

1895, Mar. 5. Behrens, Gustav. *Holly Royde, Withington, Manchester.*

1898, Nov. 29. Behrens, Walter L. 22, *Oxford Street, Manchester.*

1868, Dec. 15. Bickham, Spencer H., F.L.S. *Underdown, Ledbury.*

1901, Nov. 12. Bles, A. J. S. *Palm House, Higher Broughton, Manchester.*

1896, April 28. Bolton, Herbert, F.R.S.E. *The Museum, Bristol.*

1896, Oct. 6. Bowman, F.H., D.Sc., F.R.S.E. *Spinningfield, Deansgate, Manchester.*

1896, Feb. 18. Bowman, George, M.D. 594, *Stretford Road, Old Trafford, Manchester.*

1875, Nov. 16. Boyd, John. *Barton House*, 11, *Didsbury Park, Didsbury, Manchester.*

1902, Nov. 4. Bradley, H. W. *Woodside, Wilmslow, Cheshire.*

1889, Oct. 15. Bradley, Nathaniel, F.C.S. *Sunnyside, Whalley Range, Manchester.*

1896, Nov. 17. Broderick, Lonsdale, F.C.A. *Somerby, Wilmslow, Cheshire.*

Date of Election.

1861, April 2. Brogden, Henry, F.G.S., M.I.Mech.E. *Hale Lodge, Altrincham, Cheshire.*

1889, April 16. Brooks, Samuel Herbert. *Slade House, Levenshulme, Manchester.*

1860, Jan. 24. Brothers, Alfred. *Handforth, near Manchester.*

1886, April 6. Brown, Alfred, M.A., M.D. *Sandycroft, Higher Broughton, Manchester.*

1889, Jan. 8. Brownell, T. W., F.R.A.S. 64, *Upper Brook Street, Manchester.*

1902, Oct. 21. Bruton, F.A., M.A. 56, *Central Road, West Didsbury, Manchester.*

1889, Oct. 15. Budenberg, C. F., M.Sc., M.I.Mech.E. *Bowdon Lane, Marple, Cheshire.*

1894, Nov. 13. Burton, William, F.C.S. *The Hollies, Clifton Junction, near Manchester.*

1903, Nov. 3. Capper, Stewart Henbest, M.A., Professor of Architecture in the Victoria University of Manchester. 337, *Moss Lane East, Manchester.*

1899, Feb. 7. Chapman, D. L., M.A., Assistant Lecturer and Demonstrator of Chemistry in the Victoria University of Manchester. *Owens College, Manchester.*

1901, Nov. 26. Chevalier, Reginald C., M.A., Mathematical Master at the Manchester Grammar School. 43, *Lansdowne Road, West Didsbury, Manchester.*

1902, Nov. 4. Clerk, Dugald, M.Inst.C.E., F.C.S. 18, *Southampton Buildings, Chancery Lane, London, W.C.*

1901, Nov. 12. Coignou, Caroline, Science Mistress at the Manchester High School for Girls. 60, *Cecil Street, Greenheys, Manchester.*

1895, April 30. Collett, Edward Pyemont. 8, *St. John Street, Manchester.*

1884, Nov. 4. Corbett, Joseph. *Town Hall, Salford.*

1903, Oct. 20. Core, William Hamilton, M.Sc. *Groombridge House, Withington, Manchester.*

1895, Nov. 12. Crossley, W. J., M.I.Mech.E. *Openshaw, Manchester.*

1904, Jan. 5. Darbishire, Arthur D., B.A., Assistant Lecturer and Demonstrator of Zoology in the Victoria University of Manchester. *Owens College, Manchester.*

Date of Election.

1901, Nov. 26. Darbishire, Francis V., B.A., Ph.D., Assistant Lecturer and Demonstrator of Chemistry in the Victoria University of Manchester. *Hulme Hall, Plymouth Grove, Manchester.*

1895, April 9. Dawkins, W. Boyd, M.A., D.Sc., F.R.S., Professor of Geology in the Victoria University of Manchester. *Fallowfield House, Fallowfield, Manchester.*

1894. Mar. 6. Delépine, A. Sheridan, M.B., B.Sc., Professor of Pathology in the Victoria University of Manchester. *Owens College, Manchester.*

1887, Feb. 8. Dixon, Harold Baily, M.A., F.R.S., F.C.S., Professor of Chemistry in the Victoria University of Manchester. *Owens College, Manchester.*

1898, Oct. 18. Donovan, E. W., M.I.Mech.E. *Hilton House, Prestwich, Lancs.*

1902, May 13. Ellison, Robert William. 40, *Lincroft Street, Moss Side, Manchester.*

1883, Oct. 2. Faraday, F. J., F.L.S., F.S.S. *Ramsay Lodge, Slade Lane, Levenshulme, Manchester.*

1897, Oct. 19. Faraday, W. Barnard, LL.B. *Ramsay Lodge, Slade Lane, Levenshulme, Manchester.*

1903, Dec. 15. Fishenden, Richard B., Lecturer in Photo Mechanical Processes at the Municipal School of Technology, Manchester. 311, *Moss Lane East, Manchester.*

1897, Nov. 30. Freston, H. W. *Westfield, Poynton, Cheshire.*

1898, Nov. 29. Gamble, F. W., D.Sc., Assistant Lecturer and Demonstrator of Zoology in the Victoria University of Manchester. *Owens College, Manchester.*

1896, Nov. 17. Gordon, Rev. Alexander, M.A. *Memorial Hall, Albert Square, Manchester.*

1903, Oct. 20. Guppy, Henry, M.A., Librarian of the John Rylands Library. 57, *Parsonage Road, Withington, Manchester.*

1902, April 29. Herbert, Arthur M., B.A. *Park Avenue, Timperley, Cheshire.*

1902, Jan. 7. Hewitt, David B., M.D. *Oakleigh, Northwich, Cheshire.*

Date of Election.

1889, Jan. 8. Heywood, Charles J., *Chaseley, Pendleton, Manchester.*

1895, Mar. 5. Hickson, Sydney J., M.A., D.Sc., F.R.S., Professor of Zoology in the Victoria University of Manchester. *Owens College, Manchester.*

1884, Jan. 8. Hodgkinson, Alexander, M.B., B.Sc. 18, *St. John Street, Manchester.*

1898, Nov. 29. Hopkinson, Alfred, K.C., M.A., LL.D., Vice-Chancellor of the Victoria University of Manchester. *Fairfield, Victoria Park, Manchester.*

1896, Nov. 3. Hopkinson, Edward, D.Sc., M.Inst.C.E. *Ferns, Alderley Edge, Cheshire.*

1889, Oct. 15. Hoyle, William Evans, M.A., D.Sc., F.R.S.E., Director of the Manchester Museum. *Owens College, Manchester.*

1900, Oct. 16. Hutton, R. S., M.Sc., Assistant Lecturer and Demonstrator of Electro-Chemistry in the Victoria University of Manchester. *Owens College, Manchester.*

1899, Oct. 17. Ingleby, Joseph, M.I.Mech.E. *Summer Hill, Pendleton, Manchester.*

1901, Nov. 26. Jackson, Frederick. 14, *Cross Street, Manchester.*

1870, Nov. 1. Johnson, William H., B.Sc. 26, *Lever Street, Manchester.*

1878, Nov. 26. Jones, Francis, M.Sc., F.R.S.E., F.C.S. *Manchester Grammar School,* and *Beaufort House, Alexandra Park, Manchester.*

1886, Jan. 12. Kay, Thomas. *Moorfield, Stockport, Cheshire.*

1895, Nov. 12. Kirkman, W. W. *The Grange, Timperley, Cheshire.*

1903, Feb. 3. Knecht, Edmund, Ph.D., Professor of Tinctorial Chemistry at the Municipal School of Technology, Manchester. 5, *Station Road, Crumpsall, Manchester.*

1902, Feb. 4. Kolp, N. *Woodthorpe, Victoria Park, Manchester.*

1901, Oct. 29. Laidlaw, Frank F., B.A. 8, *Parsonage Road, Withington, Manchester.*

1893, Nov. 14. Lamb, Horace, M.A., LL.D., D.Sc., F.R.S., Professor of Mathematics in the Victoria University of Manchester. 6, *Wilbraham Road, Fallowfield, Manchester.*

1904, Jan. 5. Langdon, Edward Henry, Merchant. 151, *Palatine Road, West Didsbury, Manchester.*

1902, Jan. 7. Lange, Ernest F. *Fairholme,* 3, *Willow Bank, Fallowfield, Manchester.*

Date of Election.

1904, Mar. 15. Lea, Arnold W. W., M.D. 246, *Oxford Road, Manchester.*

1895, Nov. 12. Lees, Charles Herbert, D.Sc., Lecturer in Physics in the Victoria University of Manchester. *Chevy Chace, Lorne Grove, Fallowfield, Manchester.*

1903, Nov. 17. Leigh, Charles W. E., Deputy Librarian. *Owens College, Manchester.*

1902, Nov. 4. Leigh, Joseph Egerton. *The Towers, Didsbury, Manchester.*

1902, Jan. 7. Longridge, Michael, M.A., M.Inst.C.E. *Linkvretten, Ashley Road, Bowdon, Cheshire.*

1857, Jan. 27. Longridge, Robert Bewick, M.I.Mech.E. *Yew Tree House, Tabley, Knutsford, Cheshire.*

1903, Dec. 15. Maccall, William Tolmé, M.Sc., Demonstrator of Engineering in the Victoria University of Manchester. *St. Olave's, Hesketh Park, Southport.*

1898, Nov. 29. McConnel, J. W., M.A. *Wellbank, Prestwich, Lancs.*

1866, Nov. 13. McDougall, Arthur, B.Sc. *Lyndhurst, The Park, Buxton.*

1902, Mar. 4. Mandleberg, G. C. *Carlton House, Broom Lane, Higher Broughton, Manchester.*

1875, Jan. 26. Mann, J. Dixon, M.D., F.R.C.P. (Lond.), Professor of Medical Jurisprudence in the Victoria University of Manchester. 16, *St. John Street, Manchester.*

1901, Dec. 10. Massey, Herbert. *Ivy Lea, Burnage, Didsbury, Manchester.*

1896, Oct. 20. Massey, Leonard F. *Openshaw, Manchester.*

1864, Nov. 1. Mather, Sir William, M.P., M.Inst.C.E., M.I.Mech.E. *Iron Works, Salford.*

1903, Jan. 6. Mellanby, Alexander L., M.Sc., Lecturer in Engineering at the Municipal School of Technology, Manchester. 33, *Keppel Road, Chorlton-cum-Hardy, Manchester.*

1873, Mar. 18. Melvill, James Cosmo, M.A., F.L.S. *Meole-Brace Hall, Shrewsbury.*

1881, Oct. 18. Mond, Ludwig, Ph.D., F.R.S., F.C.S. *Winnington Hall, Northwich, Cheshire.*

1894, Feb. 6. Mond, Robert Ludwig, M.A., F.R.S.E., F.C.S. *Winnington Hall, Northwich, Cheshire.*

1903, Oct. 20. Moore, Frederick Craven, M.D., M.Sc., 61, *Ardwick Green, Manchester.*

1899, Mar. 7. Morris, Edgar F., M.A., F.C.S. *Grey House, Barrington Road, Altrincham, Cheshire.*

Date of Election.

1902, Feb. 18. Moss, William E., B.A. *C/o Messrs. Davies, Benachi & Co., 7, Rumford Street, Liverpool.*

1903, Nov. 3. Newbould, Herbert Simpson, B.A., Assistant Master at the Manchester Grammar School. 2, *Clyde Road, West Didsbury, Manchester.*

1873, Mar. 4. Nicholson, Francis, F.Z.S. 84, *Major Street, Manchester.*

1900, April 3. Nicolson, John T., D.Sc., Professor of Engineering at the Municipal School of Technology, Manchester. *Nant-y-Glyn, Marple, Cheshire.*

1889, April 16. Norbury, George. *Hillside, Prestwich Park, Prestwich, Lancs.*

1884, April 15. Okell, Samuel, F.R.A.S. *Overley, Langham Road, Bowdon, Cheshire.*

1903, Jan. 6. Oldham, Charles. *Brook Cottage, Knutsford, Cheshire.*

1901, Nov. 26. Paine, Standen. *Devisdale, Bowdon, Cheshire.*

1903, Oct. 20. Paton, J. Lewis, M.A., High Master, Manchester Grammar School. *North Lodge, Broughton Park, Manchester.*

1892, Nov. 15. Perkin, W. H., jun., Ph.D., F.R.S., Professor of Organic Chemistry in the Victoria University of Manchester. *Owens College, Manchester.*

1901, Oct. 29. Petavel, J. E. *Owens College, Manchester.*

1885, Nov. 17. Phillips, Henry Harcourt, F.C.S. 9, *Crawford Avenue, Bolton, Lancs.*

1902, Oct. 21. Pope, W. J., F.R.S., F.C.S., Professor of Chemistry at the Municipal School of Technology, Manchester. 16, *Hope Street, Higher Broughton, Manchester.*

1901, Nov. 12. Pratt, Edith M., M.Sc., D.Sc. *Peak House, Dukinfield, Cheshire.*

1903, Dec. 15. Prentice, Bertram, Ph.D., D.Sc., Lecturer in Chemistry, Royal Technical Institute, Salford. *Primrose Villa, Snowdon Road, Eccles.*

1903, Feb. 3. Radcliffe, L. G., F.C.S., Lecturer in Chemistry at the Municipal School of Technology, Manchester. 6, *Alma Terrace, Old Trafford, Manchester.*

1904, Feb. 2. Radford, Catherine, B.Sc. 16, *Lime Grove, Oxford Road, Manchester.*

Date of Election.

1900, Feb. 20. Ragdale, J. R. *The Beeches, Whitefield, near Manchester.*

1901, Dec. 10. Ramsden, Herbert, M.D. (Lond.), M.B., Ch.B. (Vict.). *Sunnyside, Dobcross, near Oldham, Lancs.*

1888, Feb. 21. Rée, Alfred, Ph.D., F.C.S. 15, *Mauldeth Road, Withington, Manchester.*

1901, Oct. 15. Reynolds, J. H., M.Sc., Principal, *Municipal School of Technology, Sackville Street, Manchester.*

1869, Nov. 16. Reynolds, Osborne, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in the Victoria University of Manchester. 19, *Ladybarn Road, Fallowfield, Manchester.*

1880, Mar. 23. Roberts, D. Lloyd, M.D., F.R.S.E., F.R.C.P. (Lond.). *Ravenswood, Broughton Park, Manchester.*

1897, Oct. 19. Rothwell, William Thomas. *Heath Brewery, Newton Heath, near Manchester.*

1893, Mar. 21. Schill, C. H. 117, *Portland Street, Manchester.*

1896, Nov. 17. Schmitz, Hermann Emil, M.A., B.Sc. *Manchester Grammar School,* and 25, *Swinbourne Grove, Withington, Manchester.*

1873, Nov. 18. Schuster, Arthur, Ph.D., F.R.S., F.R.A.S., Professor of Physics in the Victoria University of Manchester. *Kent House, Victoria Park, Manchester.*

1898, Jan. 25. Schwabe, Louis. *Hart Hill, Eccles Old Road, Pendleton, Manchester.*

1902, Jan. 21. Shann, T. T. *Meadow Bank, Heaton Norris, Stockport.*

1890, Nov. 4. Sidebotham, Edward John, M.A., M.B., M.R.C.S. *Erlesdene, Bowdon, Cheshire.*

1903, April 28. Sidebottom, Henry. *The Hall Cottage, Cheadle Hulme, near Stockport.*

1901, Oct. 29. Sinclair, W. J., M.D., Professor of Obstetrics and Gynæcology in the Victoria University of Manchester. *Owens College, Manchester.*

1895, Nov. 12. Southern, Frank, B.Sc. 6, *Park Avenue, Timperley, Cheshire.*

1896, Feb. 18. Spence, David. *Honeyhanger, Haslemere, Surrey.*

1901, Dec. 10. Spence, Howard. *Audley, Broad Road, Sale, Cheshire.*

1896, April 14. Stanton, Thomas E., D.Sc. *National Physical Laboratory, Bushey House, Teddington, Middlesex.*

1894, Jan. 9. Stevens, Marshall, F.S.S. 18, *Exchange Street, Manchester.*

1897, Nov. 30. Stromeyer, C. E., M.Inst.C.E. *Steam Users' Association,* 9, *Mount Street, Albert Square, Manchester.*

Date of Election.

1903, April 28. Sutton, Charles W., M.A., Librarian, *Free Reference Library, King Street, Manchester.*

1895, April 9. Tatton, Reginald A., M.Inst.C.E. Engineer to the Mersey and Irwell Joint Committee. 44, *Mosley Street, Manchester.*

1893, Nov. 14. Taylor, R. L., F.C.S., F.I.C. *Central School, Whitworth Street, Manchester.*

1873, April 15. Thomson, William, F.R.S.E., F.C.S., F.I.C. *Royal Institution, Manchester.*

1896, Jan. 21. Thorburn, William, M.D., B.Sc. 2, *St. Peter's Square, Manchester.*

1896, Jan. 21. Thorp, Thomas, F.R.A.S. *Moss Bank, Whitefield, near Manchester.*

1899, Oct. 31. Thorpe, Jocelyn F., Ph.D., Demonstrator in Organic Chemistry in the Victoria University of Manchester. *Owens College, Manchester.*

1899, Oct. 17. Todd, W. H. *Greenfield, Flixton, near Manchester.*

1873, Nov. 18. Waters, Arthur William, F.L.S., F.G.S. *Sunny Lea, Davos Dorf, Switzerland.*

1892, Nov. 15. Weiss, F. Ernest, D.Sc., F.L.S., Professor of Botany in the Victoria University of Manchester. 20, *Brunswick Road, Withington, Manchester.*

1903, Dec. 15. West, Norman, A.I.E.E., Electrical Engineer. 311, *Moss Lane East, Manchester.*

1895, April 9. Whitehead, James. *Lindfield, Fulshaw Park, Wilmslow, Cheshire.*

1901, Oct. 1. Wild, Robert B., M.D., M.Sc., M.R.C.P., Professor of Materia Medica and Therapeutics in the Victoria University of Manchester. *Broome House, Fallowfield, Manchester.*

1859, Jan. 25. Wilde, Henry, D.Sc., D.C.L., F.R.S. *The Hurst, Alderley Edge, Cheshire.*

1888, April 17. Williams, Sir E. Leader, M.Inst.C.E., M.I.Mech.E. *Spring Gardens, Manchester.*

1896, Dec. 1. Wilson, George, D.Sc., Demonstrator in Engineering in the Victoria University of Manchester. *Owens College, Manchester.*

Date of Election.

1901, Nov. 26. Wilson, William, M.A., Principal, *Royal Technical Institute, Salford.*

1903, Oct. 20. Wood, Harry Edwin, B.Sc. *The Physical Laboratory, Owens College, Manchester.*

1902, Oct. 21. Woollcott, Walter. *Westinghouse Works, Trafford Park, Manchester.*

1860, April 17. Woolley, George Stephen. *Victoria Bridge, Manchester.*

1903, Nov. 17. Worthington, John Henry William, B.A., Assistant Master at the Manchester Grammar School. 60, *Filey Road, Fallowfield, Manchester.*

1863, Nov. 17. Worthington, Samuel Barton, M.Inst.C.E., M.I.Mech.E. *Mill Bank, Bowdon,* and 37, *Princess Street, Manchester.*

1865, Feb. 21. Worthington, Thomas, F.R.I.B.A. 46, *Brown Street, Manchester.*

1895, Jan. 8. Worthington, Wm. Barton, B.Sc., M.Inst.C.E. 2, *Wilton Polygon, Cheetham Hill, Manchester.*

1897, Oct. 19. Wyatt, Charles H., M.A., *Chelford, Cheshire.*

N.B.—Of the above list the following have compounded for their subscriptions, and are therefore life members :—

Bailey, Charles, M.Sc., F.L.S.
Bradley, Nathaniel, F.C.S.
Brogden, Henry, F.G.S.
Ingleby, Joseph, M.I.Mech.E.
Johnson, William H., B.Sc.
Worthington, Wm. Barton, B.Sc.

HONORARY MEMBERS.

Date of Election.	
1892, April 26.	Abney, Sir W. de W., K.C.B., D.Sc., F.R.S. *Rathmore Lodge, Bolton Gardens South, South Kensington, London, S.W.*
1892, April 26.	Amagat, E. H., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Examinateur à l'École Polytechnique. *Avenue d'Orléans*, 19, *Paris.*
1894, April 17.	Appell, Paul, Membre de l'Institut, Professor of Theoretical Mechanics. *Faculté des Sciences, Paris.*
1892, April 26.	Ascherson, Paul F. Aug., Professor of Botany. *Universität, Berlin.*
1889, April 30.	Avebury, John Lubbock, Lord, D.C.L., LL.D., F.R.S. *High Elms, Down, Kent.*
1892, April 26.	Baeyer, Adolf von, For. Mem. R.S., Professor of Chemistry. 1, *Arcisstrasse, Munich.*
1886, Feb. 9.	Baker, Sir Benjamin, K.C.M.G., LL.D., F.R.S. 2, *Queen Square Place, Westminster, London, S.W.*
1886, Feb. 9.	Baker, John Gilbert, F.R.S., F.L.S. 3, *Cumberland Road, Kew.*
1895, April 30.	Beilstein, F., Ph.D., Professor of Chemistry. *8th Line, N. 17, St. Petersburg, W.O.*
1886, Feb. 9.	Berthelot, Marcelin P. E., For. Mem. R.S., Membre de l'Institut, Professor of Chemistry, Secrétaire perpétuel de l'Académie des Sciences. *Paris.*
1892, April 26.	Boltzmann, Ludwig, For. Mem. R.S., Professor of Physics. *Türkenstrasse 3, Vienna, IX. 1.*
1886, Feb. 9.	Buchan, Alexander, M.A., LL.D., F.R.S., F.R.S.E. 42, *Heriot Row, Edinburgh.*
1888, April 17.	Cannizzaro, Stanislao, For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Chemistry. *Reale Università, Rome.*
1889, April 30.	Carruthers, William, F.R.S., F.L.S. 14, *Vermont Road, Norwood, London, S.E.*
1903, April 28.	Clarke, Frank Wigglesworth, D.Sc. *United States Geological Survey, Washington, D.C., U.S.A.*
1866, Oct. 30.	Clifton, Robert Bellamy, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy. 3, *Bardwell Road, Banbury Road, Oxford.*

Date of Election.

1892, April 26. Curtius, Theodor, Professor of Chemistry. *Universität, Kiel.*

1892, April 26. Darboux, Gaston, Membre de l'Institut, Professor of Geometry, Faculté des Sciences, Secrétaire perpétuel de l'Académie des Sciences. 36, *Rue Gay Lussac, Paris.*

1894, April 17. Debus, H., Ph.D., F.R.S. 4. *Schlangenweg, Cassel, Hessen, Germany.*

1888, April 17. Dewalque, Gustave, Professor of Geology. *Université, Liége.*

1900, April 24. Dewar, James, M.A., LL.D., D.Sc., F.R.S., V.P.C.S., Fullerian Professor of Chemistry. *Royal Institution, Albemarle Street, London, W.*

1892, April 26. Dohrn, Dr. Anton, For. Mem. R.S. *Zoologische Station, Naples.*

1892, April 26. Dyer, Sir W. T. Thiselton, K.C.M.G., C.I.E., M.A., F.R.S., Director of the Royal Botanic Gardens. *Kew.*

1892, April 26. Edison, Thomas Alva. *Orange, N.J., U.S.A.*

1895, April 30. Elster, Julius, Ph.D. 6, *Lessingstrasse, Wolfenbüttel.*

1900, April 24. Ewing, James Alfred, M.A., F.R.S., Professor of Mechanism and Applied Mechanics. *Royal Naval College, Greenwich.*

1889, April 30. Farlow, W. G., Professor of Botany. *Harvard College, Cambridge, Mass., U.S.A.*

1900, April 24. Forsyth, Andrew Russell, M.A., Sc.D., F.R.S., Sadlerian Professor of Pure Mathematics. *Trinity College, Cambridge.*

1889, April 30. Foster, Sir Michael, K.C.B., M.P., M.A., M.D., LL.D., Sec. R.S., Professor of Physiology. *Trinity College, Cambridge.*

1892, April 26. Fürbringer, Max, Professor of Anatomy. *Grossherz. Universität, Jena.*

1892, April 26. Gegenbaur, Carl, For. Mem. R.S., Professor of Anatomy. 57, *Leopoldstrasse, Heidelberg.*

1900, April 24. Geikie, James, D.C.L., LL.D., F.R.S., Murchison Professor of Geology and Mineralogy. *Kilmorle, Colinton Road, Edinburgh.*

1895, April 30. Geitel, Hans. 6, *Lessingstrasse, Wolfenbüttel.*

1894, April 17. Glaisher, J. W. L., Sc.D., F.R.S., Lecturer in Mathematics. *Trinity College, Cambridge.*

1894, April 17. Gouy, A., Professor of Physics. *Faculté des Sciences, Lyons.*

Date of Election.

1900, April 24. Haeckel, Ernst, Ph.D., Professor of Zoology. *Zoologisches Institut, Jena.*

1894, April 17. Harcourt, A. G. Vernon, M.A., D.C.L., F.R.S., V.P.C.S. *St. Clare, Ryde, Isle of Wight.*

1894, April 17. Heaviside, Oliver, F.R.S. *Bradley View, Newton Abbot, Devon.*

1892, April 26. Hill, G. W. *West Nyack, N. Y., U.S.A.*

1888, April 17. Hittorf, Johann Wilhelm, Professor of Physics. *Polytechnicum, Münster.*

1892, April 26. Hoff, J. van't, Ph.D., For. Mem. R.S., Professor of Chemistry. 2, *Uhlandstrasse, Charlottenburg, Berlin.*

1892, April 26. Hooker, Sir Joseph Dalton, G.C.S.I., C.B., D.C.L., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *The Camp, Sunningdale, Berks.*

1869, Jan. 12. Huggins, Sir William, O.M., K.C.B., LL.D., D.C.L., P.R.S., F.R.A.S., Corr. Memb. Inst. Fr. (Acad. Sci.). 90, *Upper Tulse Hill, Brixton, London, S.W.*

1851, April 29. Kelvin, William Thomson, Lord, O.M., G.C.V.O., M.A., D.C.L., LL.D., F.R.S., F.R.S.E., For. Assoc. Inst. Fr. (Acad. Sci.). *Netherhall, Largs, Ayrshire.*

1892, April 26. Klein, Felix, Ph.D., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Mathematics. 3, *Wilhelm Weber Strasse, Göttingen.*

1894, April 17. Königsberger, Leo, Professor of Mathematics. *Universität, Heidelberg.*

1892, April 26. Ladenburg, A., Ph.D., Professor of Chemistry. 3, *Kaiser Wilhelm Strasse, Breslau.*

1887, April 19. Langley, S. P., For. Mem. R.S. *Smithsonian Institution, Washington, U.S.A.*

1902, May 13. Larmor, Joseph, M.A., D.Sc., LL.D., Sec. R.S., F.R.A.S. *St. John's College, Cambridge.*

1892, April 26. Liebermann, C., Professor of Chemistry. 29, *Matthäi-Kirch Strasse, Berlin.*

1887, April 19. Lockyer, Sir J. Norman, K.C.B., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *Science School, South Kensington, London, S.W.*

1902, May 13. Lodge, Sir Oliver Joseph, D.Sc., LL.D., F.R.S., Principal of the University of Birmingham. *The University, Birmingham.*

1900, April 24. Lorentz, Henrik Anton, Professor of Physics. *Hooigracht, 48, Leyden.*

Date of Election.

1892, April 26. Marshall, Alfred, M.A., Professor of Political Economy. *Balliol Croft, Madingley Road, Cambridge.*

1892, April 26. Mascart, E. E. N., For. Mem. R.S., Membre de l'Institut, Professor at the Collège de France. 176, *Rue de l'Université, Paris.*

1889, April 30. Mendeléeff, D., Ph.D., For. Mem. R.S. *Université, St. Petersburg.*

1901, April 23. Metchnikoff, Élie, D.Sc., For. Mem. R.S. *Institut Pasteur, Paris.*

1895, April 30. Mittag-Leffler, Gösta, D.C.L. (Oxon.), For. Mem. R.S., Professor of Mathematics. *Djursholm, Stockholm.*

1892, April 26. Moissan, H., Membre de l'Institut, Professor of the Faculté des Sciences à la Sorbonne. 7, *Rue Vauquelin, Paris.*

1894, April 17. Murray, Sir John, K.C.B., LL.D., D.Sc., F.R.S. *Challenger Lodge, Wardie, Edinburgh.*

1894, April 17. Neumayer, Professor G., For. Mem. R.S., Director of the Seewarte. *Hohenzollern Strasse*, 9, *Neustadt an der Haardt, Germany.*

1887, April 19. Newcomb, Simon, For. Mem. R.S., For. Assoc. Inst. Fr. (Acad. Sci.), Professor of Mathematics and Astronomy. 1620, *P Street, Washington, D.C., U.S.A.*

1902, May 13. Osborn, Henry Fairfield, Professor of Vertebrate Palæontology. *Columbia College, New York, U.S.A.*

1894, April 17. Ostwald, W., Professor of Chemistry. 2/3, *Linnéstrasse, Leipsic.*

1899, April 25. Palgrave, R. H. Inglis, F.R.S., F.S.S. *Belton, Great Yarmouth.*

1892, April 26. Perkin, W. H., LL.D., Ph.D., F.R.S., V.P.C.S. *The Chestnuts, Sudbury, Harrow.*

1894, April 17. Pfeffer, Wilhelm, For. Mem. R.S., Professor of Botany. *Botanisches Institut, Leipsic.*

1892, April 26. Poincaré, H., For. Mem. R.S., Membre de l'Institut, Professor of Astronomy. 63, *Rue Claude Bernard, Paris.*

1892, April 26. Quincke, G. H., For. Mem. R.S., Professor of Physics. *Universität, Heidelberg.*

1899, April 25. Ramsay, Sir William, K.C.B., Ph.D., F.R.S., Professor of Chemistry. 12, *Arundel Gardens, Notting Hill, London, W.*

Date of Election.

1849, Jan. 23. Rawson, Robert, F.R.A.S. *Havant, Hants.*

1886, Feb. 9. Rayleigh, John William Strutt, Lord, O.M., M.A., D.C.L. (Oxon.), LL.D. (Univ. McGill), F.R.S., F.R.A.S., Corr. Memb. Inst. Fr. (Acad. Sci.). *Terling Place, Witham, Essex.*

1900, April 24. Ridgway, Robert, Curator of the Department of Birds, U.S. National Museum. *Brookland, District of Columbia, U.S.A.*

1897, April 27. Roscoe, Sir Henry Enfield, B.A., LL.D., D.C.L., F.R.S., V.P.C.S., Corr. Memb. Inst. Fr. (Acad. Sci.). 10, *Bramham Gardens, Earl's Court, London, S.W.*

1889, April 30. Routh, Edward John, D.Sc., F.R.S. *Newnham Cottage, Queen's Road, Cambridge.*

1894, April 17. Sanderson, Sir J. S. Burdon, Bart., M.A., M.D., F.R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Regius Professor of Medicine in the University of Oxford. 64, *Banbury Road, Oxford.*

1902, May 13. Scott, Dukinfield Henry, M.A., Ph.D., F.R.S., F.L.S., Honorary Keeper of the Jodrell Laboratory, Royal Botanic Gardens, Kew. *Old Palace, Richmond, Surrey.*

1892, April 26. Sharpe, R. Bowdler, LL.D., F.L.S., F.Z.S. *British Museum (Natural History), Cromwell Road, London, S.W.*

1892, April 26. Solms, H., Graf zu, Professor of Botany. *Universität, Strassburg.*

1869, Dec. 14. Sorby, Henry Clifton, LL.D., F.R.S., F.L.S., F.G.S. *Broomfield, Sheffield.*

1886, Feb. 9. Strasburger, Eduard, D.C.L., For. Mem. R.S., Professor of Botany. *Universität, Bonn.*

1895, April 30. Suess, Eduard, Ph.D., For. Mem. R.S., For. Assoc. Inst. Fr. (Acad. Sci.), Professor of Geology. 9, *Africanergasse, Vienna.*

1895, April 30. Thomson, Joseph John, M.A., Sc.D., F.R.S., Professor of Experimental Physics. 6, *Scrope Terrace, Cambridge.*

1894, April 17. Thorpe, T. E., C.B., Ph.D., D.Sc., LL.D., F.R.S., V.P.C.S. *Government Laboratory, Clement's Inn Passage, Strand, London, W.C.*

1900, April 24. Tower, Beauchamp, M.Inst.C.E. *Warley Mount, Brentwood, Essex.*

Date of Election.

1894, April 17. Turner, Sir William, K.C.B., M.B., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy. 6, *Eton Terrace, Edinburgh.*

1886, Feb. 9. Tylor, Edward Burnett, D.C.L. (Oxon), LL.D. (St. And. and McGill Colls.), F.R.S., Professor of Anthropology. *Museum House, Oxford.*

1894, April 17. Vines, Sidney Howard, M.A., D.Sc., F.R.S., Sherardian Professor of Botany. *Headington Hill, Oxford.*

1894, April 17. Warburg, Emil, Professor of Physics. *Physikalisches Institut, Neue Wilhelmstrasse, Berlin.*

1894, April 17. Ward, H. Marshall, D.Sc., F.R.S., Professor of Botany. *Botanical Laboratory, New Museums, Cambridge.*

1894, April 17. Weismann, August, Professor of Zoology. *Universität, Freiburg i. Br.*

1886, Feb. 9. Young, Charles Augustus, Professor of Astronomy. *Princeton College, Princeton, N.J., U.S.A.*

1888, April 17. Zirkel, Ferdinand, For. Mem. R.S., Professor of Mineralogy. *Thralstrasse,* 33, *Leipsic.*

CORRESPONDING MEMBERS.

1850, April 30. Harley, Rev. Robert, Hon. M.A. (Oxon), F.R.S., F.R.A.S., Hon. Memb. R.S. Queensland. *Rosslyn, Westbourne Road, Forest Hill, London, S.E.,* and *The Athenæum Club, London, S.W.*

1882, Nov. 14. Herford, Rev. Brooke, D.D. 91, *Fitzjohn's Avenue, Hampstead, London, N.W.*

1859, Jan. 25. Le Jolis, Auguste François, Ph.D., Archiviste-perpétuel of the Societé des Sciences Naturelles, Cherbourg. *Cherbourg.*

Awards of the Wilde Medal under the conditions of the Wilde Endowment Fund.

1896. Sir GEORGE G. STOKES, Bart., F.R.S.

1897. Sir WILLIAM HUGGINS, K.C.B., F.R.S.

1898. Sir JOSEPH DALTON HOOKER, G.C.S.I., C.B., F.R.S.

1899. Sir EDWARD FRANKLAND, K.C.B., F.R.S.

1900. Rt. Hon. LORD RAYLEIGH, F.R.S.

1901. Dr. ÉLIE METCHNIKOFF, For.Mem.R.S.

1903. Prof. FRANK W. CLARKE, D.Sc.

Awards of the Dalton Medal.

1898. EDWARD SCHUNCK, Ph.D., F.R.S.

1900. Sir HENRY E. ROSCOE, F.R.S.

1903. Prof. OSBORNE REYNOLDS, LL.D., F.R.S.

Awards of the Premium under the conditions of the Wilde Endowment Fund.

1897. PETER CAMERON.

1898. JOHN BUTTERWORTH, F.R.M.S.

1899. CHARLES H. LEES, D.Sc.

1900. Prof. A. W. FLUX, M.A.

1901. THOMAS THORP.

THE WILDE LECTURES.

1897. (July 2.) "On the Nature of the Röntgen Rays." By Sir G. G. STOKES, Bart., F.R.S. (*28 pp.*)

1898. (Mar. 29.) "On the Physical Basis of Psychical Events." By Sir MICHAEL FOSTER, K.C.B., F.R.S. (*46 pp.*)

1899. (Mar. 28.) "The newly discovered Elements; and their relation to the Kinetic Theory of Gases." By Prof. WILLIAM RAMSAY, F.R.S. (*19 pp.*)

1900. (Feb. 13.) "The Mechanical Principles of Flight." By the Rt. Hon. LORD RAYLEIGH, F.R S. (*26 pp.*)

1901. (April 22.) "Sur la Flore du Corps Humain." By Dr. ÉLIE METCHNIKOFF, For.Mem.R.S. (*38 pp.*)

1902. (Feb. 25.) "On the Evolution of the Mental Faculties in relation to some Fundamental Principles of Motion." By Dr. HENRY WILDE, F.R.S. (*34 pp., 3 pl.*)

1903. (May 19.) "The Atomic Theory." By Professor F. W. CLARKE, D.Sc. (*32 pp.*)

1904. (Feb. 23.) "The Evolution of Matter as revealed by the Radio-Active Elements." By FREDERICK SODDY, M.A. (*42 pp.*)

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MEMOIRS AND PROCEEDINGS

OF

THE MANCHESTER LITERARY & PHILOSOPHICAL SOCIETY.

1903-1904.

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Alexejeff (W. G.) Die Mathematik als Grundlage der Kritik wissenschaftlich-philosophischer Weltanschauung. 1903.

Amsterdam.—Académie Royale des Sciences. Feriae Aestivae Carmen Praemio Aureo ornatum in Certamine Poetico Hoeufftiano. 1903.

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