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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.

CONTENTS.

INAUGURAL ADDRESS.

MEMOIRS.

INDEX.

M = Memoirs. P = Proceedings.

Manchester Memoirs, Vol. lvi. (1911-12).

INAUGURAL ADDRESS.

Researches on Heredity in Plants.

By THE PRESIDENT,

Professor F. E. WEISS, D.Sc., F.L.S.

October 3rd, 1911.

Ever since the discovery by Sprengel of the cross fertilisation of flowers by insects, efforts were made by various experimenters to ascertain whether the pollen of one species could fertilise the ovule of a different species, whether in fact the characters of two distinct species could be combined in a hybrid organism. Kœlreuter, Knight and Gaertner were among the first to make definite experiments in this direction, and a general summary of the very considerable amount of work done during about 120 years was compiled and published by Focke in 1881. With two brilliant exceptions, however, hardly any of the investigators were able to formulate definite laws governing the production of hybrids and the inheritance of parental characters, and Focke's encyclopædic work unfortunately laid no stress on the important generalisations of Naudin and of Mendel.

The earlier experimenters had concluded that hybrids between different species exhibited some characters of both parents, and Macfarlane, in his comparison of the minute structure of plant hybrids, published in 1891, laid it down as fundamental that the hybrid represented an organism exactly intermediate in all its characters between those of its two parents. This generalisation was, however, based on the examination of a somewhat limited

April 22nd, 1912.

number of plant hybrids, and the investigations, however careful, were confined to a consideration of the first hybrid generation.

It was not until the spring of 1900 that three experimenters—De Vries, Correns and Tschermack—drew attention to the important work of the abbot Mendel, published in 1865, on the laws of inheritance in hybrids, which, though referred to by Focke in his *Pflanzenbastardierung*, had remained unappreciated for half a century, probably owing to its having been published in a periodical of very limited circulation.

In the same way the important experiments made by Naudin about the same time (1856-1862), and the laws he deduced from his experiments, have received little notice until quite recently, when Blaringhem has drawn attention to the work of this investigator, and has republished the generalisations, which are in striking agreement with some of those of Mendel.

Mendel's experiments were carried on partly with different races or strains of cultivated plants (peas), partly with various species of hawk-weeds. In the former case he pollinated varieties of the common pea with pollen of varieties differing from the maternal plant in one or more characters. One of the distinctive features of Mendel's work was the recognition of these unit characters and their behaviour in the first and subsequent hybrid generations. One of the simplest instances of the independence of unit character is seen in the easily repeated experiment of Mendel, in which he pollinated the flowers of a variety of the common pea characterised by its round seeds with the pollen of a variety bearing wrinkled seeds. The resulting hybrid produced round seeds, so that of the two allelomorphic characters, as they have been termed, roundness of seeds is dominant, while wrinkledness is recessive in the first hybrid generation (*f* 1). If the matter is followed further, however, by pollinating the flower of the hybrid with its own pollen, then in the second hybrid generation (*f* 2), though the majority of the offspring show the dominant character, a certain smaller proportion show a reversion to the recessive form. Working with a very large number of plants, Mendel was able to show that the numerical ratio of dominants and recessives in the second hybrid generation was practically as 3 : 1.

This simple numerical ratio was found by Mendel to apply not only to these particular characters of roundness and wrinkledness, but equally to all unit characters when treated singly, and the numerous investigators who have continued Mendel's experiments in a great variety of plants and animals have in almost every case obtained the same numerical results. The deduction drawn from this simple numerical ratio is also in complete agreement with what is known of the development of the reproductive cells in both the vegetable and animal kingdom. According to Mendel's interpretation of his results, the first hybrid generation, while displaying only the dominant, yet contains in a latent form the recessive character, and these two characters become segregated in the reproductive cells of the plant, so that each egg cell and each pollen grain possesses only one of them. From self-fertilisation of the hybrid, therefore, four possible combinations might result. The egg cell bearing the dominant character D might be fertilised by pollen bearing the dominant character (d) or by pollen bearing the recessive character (r). The egg cell bearing the recessive character (R) might be pollinated by either form of pollen (d or r). The four resultant individuals would therefore be represented by the letters :

$$Dd, \quad Dr, \quad Rd, \quad Rr.$$

Of these the first three contain the dominant character, whether derived from the egg cell or the pollen grain, and would consequently all appear alike and resemble the dominant parent; while the fourth individual would receive a double dose of the recessive character and be purely recessive. Thus the simple numerical ratio of 3 to 1 would be accounted for, and this explanation is in harmony with the fact that during the development of the reproductive cells of plants and animals, we have a remarkable reduction in the complexity of the nucleus, generally taken to be the carrier of hereditary character, which might well correspond with the assumed segregation of parental characters.

Further consideration of the nature of the three dominant forms produced by the four possible combinations of unit character will show that only the first (*Dd*), which obtained its dominant character from both its parents, is a pure bred dominant (homozygous), while the other two (*Dr* and *Rd*) are, like the first hybrid generation, impure, containing the recessive constituent derived in one case from the male and in the other case from the female parent. If fertilised with their own pollen they would therefore in the next generation (*f* 3) segregate out exactly as *f* 1 had done when self-fertilised. This, too, was clearly proved by Mendel, and has been repeatedly confirmed. Of the 75 % of dominants in the *f* 2 generation, only 25 % are pure and breed true.

The two laws of dominance of certain unit characters in the first hybrid generation and of segregation of the characters in the second hybrid generation Mendel found to be true for a variety of racial characteristics in peas, such as colour of the seed coat, colour of the cotyledons, difference in the form of the ripe pods, etc. Since the rediscovery of Mendel's work, they have been shown to hold good for a still greater variety of characters in an extensive series of plants and animals.

De Vries, who was one of the first to draw attention to Mendel's work, took for one of his experiments the interesting cut-leaved variety of the Greater Celandine, *Chelidonium majus* var. *laciniatum*, which is said to have appeared suddenly as a sport in the Botanical Gardens of a pharmacist in Heidelberg in the year 1590. This interesting form is characterised by the laciniate condition of its leaves and petals. When pollinated with pollen of the normal form it produces a hybrid which is hardly distinguishable from normal plant. In the second hybrid generation, however, 25 % of the plants are found to revert back to the type of the cut-leaved maternal parent.

During the past summer I have repeated this experiment of De Vries and obtained 209 recessives and 612 dominants. They are easily recognisable even in the seedling condition by their more deeply cleft leaves and the rather sharper teeth of the margin (see *Figs.* 1 and 2). De Vries also showed that if the hybrid is pollinated with the pollen of the recessive laciniate parent, the numerical ratio of dominants and recessives is 2 : 1, as would be expected from the Mendelian hypothesis. It is of interest in connection with this example of Mendelian inheritance to note that the original form is dominant over the more recent sport, the cut-leaved form, and though not without exception it is found very generally that the more ancient form is dominant to the newer variety.

An interesting case of colour inheritance has occupied my attention during the past two years, and offers a very striking illustration of the Mendelian laws of inheritance.

A well-known variety of the common Pimpernel (*Anagallis arvensis*) bears bright blue flowers, which are in strange contrast with the scarlet flowers of the normal form. Although small, the flowers can be readily cross-pollinated, and the hybrid or cross between these two varieties has scarlet flowers, exactly like those of the scarlet parent. In the second hybrid or filial generation (*f* 2), however, 25 % of the plants bear blue flowers, while 75 % have scarlet flowers. A bed in which a number of these offspring have been planted out as seedlings offers, when the plants are in flower, a very remarkable and striking illustration of the law of segregation of characters.

The same result is obtained when plants of the pale salmon or pink varieties are crossed with the blue form.

Complete dominance of one of the parental characters is, however, not an invariable rule. In some cases the first filial generation shows approximately an intermediate condition of the parental features. Thus Correns has shown that crossing a white and red form of Mirabilis results in a plant with pink flowers. If this plant, however, is self-fertilised, the resulting plants produce white, pink, and red flowers in the proportion of 1 : 2 : 1. In this case the heterozygous pink form can always be clearly distinguished from the homozygous red, though they must both be regarded as dominants.

Considerable interest attaches to the curious results obtained by Bateson in crossing two white sweet peas belonging to the variety Emily Henderson. The resultant cross, instead of bearing white flowers, as might have been expected, produced parti-coloured flowers (red and purple), very like the form known as Purple Invincible. The explanation of this curious phenomenon lies in the fact, now definitely established, that the production of colour in these flowers depends on two factors, which must both occur in one plant before the flowers can become coloured. In the two white forms these factors were segregated, hence the absence of colour in the two parents, but when crossed the two factors unite, and a coloured form results. In the (*f* 2) generation, both white and coloured forms were produced from the coloured cross, indicating that a segregation had taken place in some of the offspring of the two-colour-producing factors.

Besides dealing with isolated pairs of allelomorphic characters, Mendel experimented also with plants differing in two characters from one another. For these investigations he was also able to use the garden pea. Selecting for one parent a variety characterised by green round seeds, and for the other a form with yellow wrinkled seeds, he obtained a cross, the seeds of which were yellow and round, as these two characters are dominant to greenness and wrinkledness. Allowing the flowers of this first hybrid generation (*f* 1) to be self-fertilised, he obtained four different types of plants:

a. Plants with yellow, round seeds (two dominant characters).

b. Plants with yellow, wrinkled seeds (one dominant and one recessive character).

c. Plants with green, round seeds (one recessive and one dominant character).

d. Plants with green, wrinkled seeds (two recessive characters).

The numerical ratios of these forms were as

$$9 : 3 :: 3 : 1$$

for the respective gametes, *i.e.*, egg cells and pollen grains would be of the four types, *YR* (yellow round), *Yw* (yellow wrinkled), *gR* green round, and *gw* (green wrinkled), the capital standing for the dominant character. Consequently there would be sixteen possible cross pollinations. These combinations may be graphically represented as follows:—

$YR \times YR$	$Yw \times YR$	$gR \times YR$	$gw \times YR$
$YR \times Yw$	$Yw \times Yw$	$gR \times Yw$	$gw \times Yw$
$YR \times gR$	$Yw \times gR$	$gR \times gR$	$gw \times gR$
$YR \times gw$	$Yw \times gw$	$gR \times gw$	$gw \times gw$

Each combination with a Y and R would give a form characterised by the two dominant characters, and it will be seen that they occur in nine combinations, while the single dominant character Y occurs in three, and the single dominant R also in three. The two recessive characters without dominants only occur in one of the sixteen combinations. Thus the ratios 9 : 3 : 3 : 1 is accounted for.

This numerical ratio of coupled characters has been confirmed in several other instances by later experimenters both in the case of animals and of plants.

In some instances what appear at first sight to be unit characters have turned out to be pairs of allelomorphs, showing the ratios 9 : 3 : 3 : 1 in place of the 3 : 1 ratio. This has been shown to be the case especially in cases of heredity of colour, where certain unseen colour factors or determiners come into play, such as are referred to above in connection with the mating of two white varieties of sweet peas.

Again, differences in colour of flowers may be due to very distinct causes. Thus in the Common Avens (*Geum urbanum*) the yellow colour of the petals is due to the presence of yellow colour in the plastids of the petals. In the Water Avens (*Geum rivale*), on the other hand, the red colour is due to a red sap, particularly well developed in the cells on the outside of the petals. The hybrid between these two species, which is often found in the limestone dales in Derbyshire, presents both characters. It shows a blending of other characters as well, and deserves its name *Geum intermedium.* (See *Pl., Figs.* 3, 4 and 5.)

It can be easily produced artificially, and in the second hybrid generation (*f* 2) I have found it to produce plants some of which have completely red flowers, others with yellow flowers devoid of red colour, and, again, a few plants with absence of both pigments, and therefore presenting pure white flowers. (*Pl., Fig.* 6.) The throwing off of these plants with white flowers may be due to the fact that the red colour (*anthocyanin*) may be caused, as has been shown in other cases, by two factors, which must be combined in the same individual before the colour is produced, or possibly it would be simpler to suggest that we are dealing with two pairs of allelomorphic characters—(*a*) presence of red sap and absence of red sap, (*b*) presence of yellow plastids and absence of yellow plastids.

In this case we should obtain one plant with absence of red sap and absence of yellow plastids, *i.e.*, with white flowers, out of every 16 plants in the *f*2 generation. Unfortunately, the plants raised up to the present are too few to give any definite numerical ratios.

It is interesting in this connection to record the fact that I have obtained plants with pure white flowers in the *f*2 generation from the hybrids between the Primrose *(Primula acaulis)* and the true Oxlip *(Primula elatior)*, both of which have yellow flowers.

There has been much speculation as to whether the sexes (male and female) represent a pair of allelomorphic characters, following Mendel's laws of inheritance, and some experiments have been undertaken to elucidate this problem.

In the vegetable kingdom the problem is complicated by the fact that the flowering plants, which are the most easy to experiment with, are generally hermaphrodite, *i.e*, bear both the pollen and the ovules in the same flower. Experiments have, however, been made by Correns[1] on the Bryony, which has unisexual flowers, monoecious in *Bryonia alba* and dioecious, *i.e.*. on separate plants, in *Bryonia dioica.* The results of his experiments lead him to the conclusion that in *Bryonia dioica* the male is heterozygous in sex, maleness being dominant, while the female plant is homozygous. The mating of the two would therefore give an equal number of male and of female plants. Professor Bateson on the other hand considers that the results obtained by Correns might possibly be explained by taking femaleness to be dominant, and the female to be heterozygous in sex. This would be more in agreement with certain cases in the animal kingdom, which seem only explicable by such a theory. To quote Bateson, "the evidence from the descent of the dominant sex-limited diseases such as colour-blindness, and of the horns in sheep is also consistent with the same view, namely, that femaleness is due to the presence of a dominant factor. For in these examples there is evidently some additional element present in the female which inhibits or suppresses the operations of the sex-limited dominant, and that additional element may not improbably be the factor for femaleness."

As an example of the practical application of Mendelian principles, I may, in conclusion, refer to the

[1] Correns, C. Bestimmung und Vererbung des Geschlechtes, Leipzig, Borntraeger, 1907.

experiments made by Prof. Biffen with various varieties of wheats. The strains of British wheats which are remarkable for their heavy crops are unfortunately not of such value as the hard, flinty varieties of the Canada and America, as they contain less gluten, the substance which gives to the flour good baking properties ; moreover many of the British wheats have been very susceptible to the fungus producing the rust of wheat. Biffen's experiments lead him to believe that richness in gluten and immunity (*i.e.*, comparative immunity) to disease are unit characters giving simple Mendelian ratios, and he has consequently been able to unite these desirable qualities with heavy cropping capacity in wheats suitable for the British climate.

Similar useful investigations have been carried on by Nilsson-Ehle, the head of the experimental farm in Sweden, and confirm to some extent the conclusions of Biffen. But the Swedish investigator finds[2] that though strains of different degrees of susceptibility or immunity to disease (rust of wheat) segregate out from the second and subsequent hybrid generations of wheats, the fluctuation in respect to this character is often greater than the degree of immunity of the two parents, *i.e.*, some of the offspring in (f2) and (f3) generations are more susceptible to disease than the more susceptible parent, and some of the offspring are more resistant than the resistant one. The offspring, too, of equally resistant forms do not show equal resistance, but considerable variation in this respect. He concludes, therefore, that susceptibility or immunity is not a unit character, but is dependent on several factors, which may combine in various ways and thus determine the appearance of considerable fluctuations in this respect.

[2] H. Nilsson-Ehle. Kreuzungsuntersuchungen an Hafer und Weizen. Lund Universitets Arskrifter. Bd. 7, No. 6, 1911.

Exact statistical experiments regarding the inheritance of immunity and susceptibility to disease in plants are however peculiarly difficult to conduct, and have only been undertaken by very few investigators, so that we shall have to remain content for the present with the general conclusion that these peculiarities, whether of the nature of unit characters or combinations of such, behave in a general way like other distinctive characters of living organisms.

That these and similar investigations on plants and animals are of far-reaching importance, who can doubt? A general understanding, indeed, of the laws of inheritance, which seem to be so remarkably uniform in the vegetable and animal kingdoms, is not only essential for the advance of the biological sciences, but is a basis for the economic and social progress of mankind.

EXPLANATION OF PLATE.

Fig. 1. Seedling of the Greater Celandine (*Chelidonium majus*).

Fig. 2. Seedling of the cut-leaved variety of the Celandine (*Chelidonium majus* var. *laciniatum*).

Fig. 3. Flower of the Water Avens (*Geum rivale*).

Fig. 4. Flowers of *Geum intermedium*, the hybrid between the Water Avens and the Common Avens. Note the intermediate curving of the flower stalk.

Fig. 5. The Common Avens (*Geum urbanum*), with small erect flowers.

Fig. 6. One of the descendants in the second filial (*f* 2) generation of *Geum intermedium*, with white petals. The flower had the drooping habit of *Geum rivale*, but shorter petals.


1
2
3
4
5
6

I. Mersenne's Numbers.

By H. J. Woodall, A.R.C.Sc. (Lon.).

(*Received October 6th, 1911. Read October 17th, 1911.*)

[The author desires to express his thanks to Lt.-Col. Cunningham, R.E., for help in writing this note.]

In 1644 Mersenne made the assertion that the only values of p, not greater than 257, which make $2^p - 1$ a prime are:—

1, 2, 3, 5, 7, 13, 17, 19, 31, 67, 127, 257.

He published no proof of his statement, nor any indication as to how he arrived at it. Up to the present time it has only been partly verified. Only two errors have been found, viz.:—

$(2^{61} - 1)$ found prime;
$(2^{67} - 1)$ found composite.

The work so far done leaves still unverified only 15 out of the 44 numbers originally affirmed composite (by Mersenne), and one affirmed prime, viz.:—

composite $p = 101, 103, 107, 109, 137, 139, 149, 157, 167,$
$173, 193, 199, 227, 229, 241$;
and prime $p = 257$.

Table I. shows the present state of the examination of this assertion.

The purpose of this paper is to put on record the method by which $2^{181} - 1$ was proved to be composite.

December 12th, 1911.

MERSENNE'S NUMBERS.

TABLE I.

p	$2^p - 1$.	Species.	Authority.
1	1	prime	
2	3	prime	
3	7	prime	
5	31	prime	
7	127	prime	
11	23 × 89	comp.	
13	8191	prime	
17	131071	prime	
19	524287	prime	
23	47 × 178481	comp.	Fermat.
29	233 × 1103 × 2089	comp.	Euler.
31	2147483647	prime	Euler.
37	223 × 616318177	comp.	Fermat.
41	13367 × 164511353	comp.	Plana.
43	431 × 9719 × 2099863	comp.	Euler.
47	2351 × 4513 × 13264529	comp.	Landry.
53	6361 × 69431 × 20394401	comp.	Landry.
59	179951 × 3203431780337	comp	Landry.
61	2305843009213693951	prime	Seelhoff.
67	193707721 × 761838257287	comp.	Prof. Cole.
71	228479 ×	comp.	Col. Cunningham.
73	439 ×	comp.	Euler.
79	2687 ×	comp.	Le Lasseur.
83	167 ×	comp.	Euler.
89	(unknown)	comp.	Lucas.
97	11447 ×	comp.	Le Lasseur.
101			
103			
107			
109			

MERSENNE'S NUMBERS.

TABLE I.—*Continued.*

p	$2^p - 1.$	Species.	Authority
113	3391 × 23279 × 65993 ×	comp.	Le Lasseur & Col. C.
127	(see below *)	prime	Lucas.
131	263 ×	comp.	Euler.
137			
139			
149			
151	18121 × 55871	comp.	Le Lasseur & Col. C.
157			
163	150287 ×	comp.	Col. Cunningham.
167			
173			
179	359 × 1433 ×	comp.	Euler & Reuschle.
181	43441 ×	comp.	Woodall.
191	383 ×	comp.	Euler.
193			
197	7487 ×	comp.	Col. Cunningham.
199			
211	15193 ×	comp.	Le Lasseur.
223	18287 ×	comp.	Le Lasseur.
227			
229			
233	1399 ×	comp.	Le Lasseur.
239	479 × 1913 × 5737 ×	comp.	E., R. & C.†
241			
251	503 × 54217 ×	comp.	Euler & Col. C.
257			

For the 15 (supposed composite) numbers still unverified, all possible factors, not greater than 500,000, have been tried by Col. Cunningham.

* $2^{127} - 1 = 170141183460469231731687303715884105727$ = prime.

† E., R. & C. = Euler, Reuschle and Col. Cunningham.

The author has been engaged for some time, in conjunction with Lt.-Col. Cunningham, R.E., in determining for all primes up to 100,000, the least exponents (ξ,) which substituted in the expression $2^{\xi}-1$, give numerical results exactly divisible by those prime numbers. When he came to the prime 43441, he found that the only possible ξ's were 181, and 5×181.

The work then proceeded thus:—

2^{45} divided by 43441 gave a remainder + 2480:

squaring this, he found that

2^{90} similarly gave a remainder + 25219:

again, squaring and doubling,

2^{181} gave a remainder of + 1,

which proved that $2^{181}-1$ is exactly divisible by the prime 43441. On performing the division (directly) the quotient was found to be

70555 26073 82835 96526 70735 14491 06106 37962 93419 66511.

About this quotient the only property that can be asserted is that "if it has a factor it must be of one of the two forms

$1448n+1$ or $1448n+1087$."

As, for the 15 supposed composite (but still unverified) numbers, all possible factors up to the comparatively high limit of 500,000 have now been examined, it is obvious that further work will be slow.

The second column of Table I. shows all the prime factors of Mersenne's numbers as now known.

The Table II. gives the forms of the only possible divisors of all numbers not yet completely examined.

TABLE II.

Forms of the only possible divisors of uncompleted Mersenne's numbers.

p			p		
71	$568n+1$,	$568n+143$	163	$1304n+1$,	$1304n+327$
73	$584n+1$,	$584n+439$	167	$1336n+1$,	$1336n+335$
79	$632n+1$,	$632n+159$	173	$1384n+1$,	$1384n+1039$
83	$664n+1$,	$664n+167$	179	$1432n+1$,	$1432n+359$
89	$712n+1$,	$712n+535$	181	$1448n+1$,	$1448n+1087$
97	$776n+1$,	$776n+583$	191	$1528n+1$,	$1528n+383$
101	$808n+1$,	$808n+607$	193	$1544n+1$,	$1544n+1159$
103	$824n+1$,	$824n+207$	197	$1576n+1$,	$1576n+1183$
107	$856n+1$,	$856n+215$	199	$1592n+1$,	$1592n+399$
109	$872n+1$,	$872n+655$	211	$1688n+1$,	$1688n+423$
113	$904n+1$,	$904n+679$	223	$1784n+1$,	$1784n+447$
127	$1016n+1$,	$1016n+255$	227	$1816n+1$,	$1816n+455$
131	$1048n+1$,	$1048n+263$	229	$1832n+1$,	$1832n+1375$
137	$1096n+1$,	$1096n+823$	233	$1864n+1$,	$1864n+1399$
139	$1112n+1$,	$1112n+279$	239	$1912n+1$,	$1912n+479$
149	$1192n+1$,	$1192n+895$	241	$1928n+1$,	$1928n+1447$
151	$1208n+1$,	$1208n+303$	251	$2008n+1$,	$2008n+503$
157	$1256n+1$,	$1256n+943$	257	$2056n+1$,	$2056n+1543$

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II. On a Collection of Arachnida and Chilopoda, made by Mr. S. A. Neave in Rhodesia, North of the Zambezi.

By S. Hirst.

(*Published by permission of the Trustees of the British Museum.*)

(*Communicated by Dr. W. M. Tattersall.*)

(*Received and read October 17th, 1911.*)

The following short report deals with the scorpions, pedipalps, and Solifugae, and the centipedes collected by Mr. Neave. Two new species (a scorpion and a species of *Solpuga*) are represented in the material, and I have taken the opportunity to publish the descriptions of two new Rhodesian arachnids obtained by other collectors. My best thanks are due to Dr. W. M. Tattersall (Keeper of the University Museum, Manchester) for his kindness in sending me this collection for examination.

CLASS ARACHNIDA.

Order Scorpiones.

1. Buthus trilineatus, Ptrs.

Centrurus trilineatus, Peters, *Mon. Ak. Berlin*, p. 515 (1862).

Buthus trilineatus, Kraepelin, *Das Tierreich*, Scorpions, etc., p. 21 (1899).

Loc. Feira District (June 1st—Aug. 15th, 1904). East bank of Loangwa, Portuguese East Africa. The British Museum possesses specimens from Madona, N.E. Rhodesia (D. MacDonald).

December 30th, 1911.

2. **Parabuthus truculentus**, sp. n.

Carapace granular throughout; superciliary ridges of ocular tubercle smooth, but the groove between them weakly granular.

Tergites of abdomen very finely granular anteriorly, the granulation of the posterior part of them much coarser but not very coarse. First *sternite* finely granular at the sides but smooth in the middle; sternites 2-4 with fine granulation at the lateral margins only; last sternite distinctly granular at the sides but only very weakly and sparsely granular in the middle; it has four keels, the outer ones being granular but the middle ones smooth.

Tail. In the central part of the stridulatory area of the first segment the granules are fused to form transverse ridges, which are especially well developed in the posterior half. In the second segment the ridges occupy practically the entire breadth of the long and narrow stridulatory area, and nearly all of them are quite continuous and uninterrupted. Intercarinal spaces distinctly granular. Segments 1-4 each with ten granular keels, and the granules of which they are composed are not exceptionally large; it is only in the posterior half, however, that the median ventral keels become distinctly granular. [See the comparison between this new species and the one from the Kalahari desert below.] Median lateral keel of the fourth segment fully developed; superior keel weak in its posterior half in the third and fourth segments; median ventral keels of the fourth coming to an end at some distance from the posterior end of the segment. Superior keel of fifth caudal segment present only in the anterior third, and consisting merely of three strong granules and a short series of weak granules; in the posterior two-thirds of this segment there is no trace of any superior keel, and the granulation of the edge of the upper surface and sides is quite fine, none of the granules being enlarged.

Hand of chela about as wide as the tibia; the movable finger a little more than twice the length of the hand-back.

Pectines with 35-36 teeth; the basal lamella of the scape does not bear any teeth, and is produced inwardly so as to form a wide lobe.

Colour yellow, except for the dorsal surface of the trunk which is brown, the first six tergites being darker than the carapace and the last tergite.

Measurements, in mm. Total length, 92; length of carapace, 9·5, of fifth caudal segment, 10.

LOC. East bank of the Loangwa, Portuguese East Africa; a single example of the female sex.

Remarks.—This new species differs, apparently, from *P. mosambicensis*, Peters (Tete, Portuguese Zambesia and Severelela in Bechuelaland), in that the superior keel of the fifth caudal segment is only present in the anterior third of the segment (see Prof. Kraepelin's notes on *P. mosambicensis* in L. Schultze, *Zool. u. anthrop. Ergebnisse e. Forschungsreise in Südafrika*, pp. 255 and 256, *Fig.* 1).

In the British Museum collection there is a male specimen of a *Parabuthus*, collected by Mr. R. J. Cunningham in the Kalahari desert, which has the stridulatory areas of the first and second caudal segments very similar to those of the new species, but the fusion of the granules, to form transverse ridges, is not so complete. It is possible that this species is the true *P. mosambicensis*, but I have not had the opportunity of comparing it with specimens from the typical locality, and therefore cannot be certain of its identity. It differs from *P. truculentus*, sp. n., in the following details of structure. Segments of tail stouter and shorter; granules of the keels of the posterior caudal segments much larger and more rounded, especially in the third and fourth segments; superior keel of third and fourth segments well developed throughout the entire length of the segment; superior keel of fifth segment well developed anteriorly, but breaking down a little before the middle so as to form a rather irregular group, or double series, of weaker granules, then continuing to the posterior end of the segment as a single series.

3. **Lychas burdoi,** E. Sim.

Isometrus burdoi, E. Simon, *Bull. Soc. ent. Belgique*, v. 26, p. lviii. (1882).

Archisometrus burdoi, Kraepelin, *Das Tierreich*, Scorpiones, etc., p. 48 (1899).

LOC. Petauke.

4. **Lychas asper,** Poc.

Isometrus asper, Pocock, *J. Linn. Soc.*, v. 23, p. 445 (1890).

Archisometrus asper, Kraepelin, *Das Tierreich*, Scorpiones, etc., p. 49 (1899).

LOC. N.E. Rhodesia (exact locality not given). E. bank of Loangwa, Portuguese East Africa. An example from Madona, N.E. Rhodesia, has recently been received at the British Museum.

This species was hitherto only known to occur in the Congo and Angola.

5. **Uroplectes planimanus,** Karsch.

Lepreus planimanus, Karsch, *Mt. Münch. ent. Ver.*, v. 3, p. 125 (1879).

Uroplectes planimanus, Kraepelin, *Das Tierreich*, Scorpiones, etc., p. 56 (1899).

Loc. N.E. Rhodesia, four examples without exact locality, labelled Aug. 4th—Aug. 20th, 1905.

6. **Uroplectes xanthogrammus,** Poc.

Uroplectes xanthogrammus, Pocock, *Ann. and Mag. Nat. Hist.* (6), 19, p. 118 (1897); *op. cit.* (7) ii., p. 431 (1898).

Loc. South of Petauke; one male specimen. E. bank of Loangwa; two females.

The specimens recorded above are the only ones of this species that have been captured so far, except the typical specimens, which were obtained on the east shore of lake Nyassa by the members of the Universities mission.

7. **Uroplectes chubbi,** sp. n.

This new species resembles *U. xanthogrammus*, Poc., so closely in structure that I am giving a short comparison between it and that species, instead of describing it in great detail.

Tergites of abdomen rather more strongly granular than those of *U. xanthogrammus*. *Tail* polished and shining, and with the punctures of the sides and ventral surface much larger and deeper (than in *U. xanthogrammus* and *U. fischeri*)—this is especially noticeable in the posterior segments of it, all the segments are also much shorter and stouter (see the measurements given at the end of this description). *Colour* darker than that of *U. xanthogrammus*, both the yellow of the body and appendages and the fuscous markings being deeper in tint. Fuscous markings of carapace resembling those of *U. xanthogrammus* in distribution; dorsal surface of abdomen, however, much more extensively darkened, for there is no pale central stripe, all the middle part of the trunk being occupied by a very broad longitudinal band of deep black, a minute median yellowish speck is present, however, at the posterior end of tergites 4—6; on each side of the trunk a longitudinal series of yellowish patches is present. Fourth segment of tail (and also the vesicle) a deeper brown than is the case in *U. xanthogrammus*, and the fifth segment quite black. Palp similar in colour to that of *U. xanthogrammus*; femora and tibiæ of legs marked with dark lines.

The following details of structure may also be useful:—*Hand*, movable finger about twice the length of the hand-back, and with twelve rows of granules. *Pectinal teeth*, seventeen in number, the basal one shorter than the others.

Measurements, in mm. Total length 32·5; length of carapace 3·75, of tail (vesicle incl.) 19·5, of fourth caudal segment 3·5, its width 2·75; length of fifth c. segment 3·75, its width 2·75.

[Length of fourth segment in a female example (type) of *U. xanthogrammus* 4, its width 2·6; length of the fifth c. segment 4·25, its width 2·75].

LOC. Rhodesia (Bulawayo ?); a single adult female, carrying its young ones, collected by Mr. E. C. Chubb.

Remarks.—The young are much paler in colour than the mother scorpion, and their abdomen has a pale central stripe as in *U. xanthogrammus*, etc.; the fourth segment of the tail is pale, like the anterior segments, only the last segment and the vesicle being fuscous.

8. **Uroplectes flavoviridis,** Ptrs.

Uroplectes flavoviridis, Peters, *Mon. Ak. Berlin*, p. 516 (1862).

Uroplectes flavoviridis, Kraepelin, *Das Tierreich*, Scorpiones, etc., p. 58 (1899).

LOC. Petauke. E. bank of Loangwa, Portuguese East Africa. In the British Museum collection there are specimens from Tete (the type locality).

The rows of granules on the movable finger of the chela are ten in number in some specimens, eleven in number in others.

9. **Pandinus viatoris,** Poc.

Scorpio viatoris, Pocock, *Ann. and Mag. Nat. Hist.*, p. 100, pl. 1, fig. 1 (1890): id., *Ann. and Mag. Nat. Hist.* (7), 2, p. 430 (1898).

Pandinus viatoris, Kraepelin, *Das Tierreich*, Scorpiones, etc., p. 122 (1899).

LOC. Petauke. Several examples of this scorpion, captured near Broken Hill, Rhodesia, have been presented to the British Museum by Mr. E. C. Chubb. It is also known to occur in Nyassaland and in German E. Africa.

10. **Opisthophthalmus carinatus,** Ptrs.

Heterometrus carinatus, Peters, *Mon. Ak., Berlin*, p. 515 (1862).

Opisthophthalmus carinatus, Kraepelin, *Das Tierreich*, Scorpiones, etc., p. 132 (1899).

LOC. N.E. Rhodesia.

11. **Hadogenes,** sp.

LOC. Feira District, a single immature example.

Order PEDIPALPI.

12. **Damon diadema**, E. Sim.

Damon diadema, E. Simon, *Bull. Soc. Zool., France*, v. 1, p. 13 (1876).

Nanodamon diadema, Pocock, *Ann. and Mag. Nat. Hist.* (6) 14, p. 293 (1894).

LOC. Feira district.

Order SOLIFUGÆ.

13. **Solpuga rhodesiana**, sp. n.

Width of *cephalic plate* less than the length of the tibia or metatarsus of the third leg, and much less than the length of the metatarsus of the palp.

Chelicera. Teeth of immovable finger rather weak; two minor teeth are present between the second large tooth and the next large tooth. Free portion of flagellum

Fig. 1a.

Fig. 1.

Fig. 1. *Solpuga rhodesiana*, sp. n., ♂, immovable finger of chelicera from the side.
Fig. 1a. Free part of flagellum from above.

short, smooth, flattened dorso-ventrally and curved backwards; when viewed from above, it is seen to be broadest at the base and to become gradually narrowed; the tip, which is slender and sharply pointed, is inclined obliquely outwards. (*Fig.* 1.)

Colour. Cephalic plate brownish; tergal plates of abdomen pale brownish, the posterior ones paler than the anterior ones, and with a narrow dark line at the posterior edge; ventral surface of body yellowish. Appendages yellowish; but the chelicera is brownish above at the base; femur of the fourth leg also brown; the distal half of the femur and the entire length of the tibia of the palp and the femora of the second and third legs and tibia of the fourth are a paler brown.

Measurements, in mm. Total length 25·5; width of cephalic plate 6·75, length of second leg 27, of third 34·5, of fourth 53·5.

[The legs of the first pair are incomplete, and their length cannot therefore be given.]

LOC. N.E. Rhodesia (exact locality not given); a single example of the male sex.

14. **Solpuga sericea**, Poc.

Solpuga sericea. Pocock, *Ann. and Mag. Nat. Hist.* (6) 20, pp. 260 and 261, *Fig.* 4 (1897).

LOC. Petauke, a male and a female. Alala Plateau, one male. The types of this species are from the Umfuli River.

15. **Solpuga celeripes**, sp. n.

Width of *cephalic plate* less than the length of the metatarsus of the palp, and about equal to the length of the tibia or metatarsus of the third leg. Fourth leg with long silky hair, as in *S. sericea*, Poc.

Chelicera. Immovable finger, with a short keel on the dorsal surface near the end, as in *S. sericea*, but the tooth which is present on the inner side, near the dorsal surface in that species, is represented by a weak granule only; two intermediate (minor) teeth are present. Free part of *flagellum* commencing above the third tooth, and moderately long; when looked at from above, it is seen to be of fairly uniform width for the greater part of its length, but becoming very slightly wider at some distance beyond the middle, then rather abruptly narrowed and setiform for the rest of its length; basal lobe of flagellum rounded in outline (*Fig.* 2).

Fig. 2a.

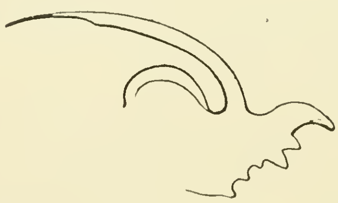

Fig. 2.

Fig. 2. *Solpuga celeripes*, sp. n., ♂, immovable finger of chelicera from the side. *Fig.* 2a. Free part of flagellum from above.

Colour. Dark markings and general coloration almost exactly the same as in *S. sericea*, but the narrow yellow stripe, which is present on either side of the dark central band of the dorsal surface of the abdomen in *S. sericea* seems to be absent (the somewhat shrunken state of the abdomen makes the markings difficult to make out, so perhaps this stripe has been overlooked).

Measurements, in mm. Total length, 11; width of cephalic plate, 3.

Loc. Salisbury, Rhodesia. Two males, collected by Mr. G. A. K. Marshall.

Remarks.—Allied to *S. sericea*, Poc. (for the localities of this species see above), and *S. zebrina*, Poc. (known from the Taru desert, British East Africa), but the flagellum is very different in shape.

CLASS CHILOPODA.

Order Scolopendromorpha.

1. **Alipes**, sp.

Loc. N.E. Rhodesia; a single specimen lacking the anal legs.

2. **Ethmostigmus trigonopodus**, Leach.

Loc. Petauke. Portuguese East Africa.

3. **Scolopendra morsitans**, L.

Loc. Petauke. Feira District. Portuguese East Africa.

4. **Cormocephalus brevicornis**, Krpln.

Cormocephalus brevicornis, Kraepelin, *Jahrb. Hamb. Wiss. Anst.* 20, p. 206 (1903).

Loc. N.E. Rhodesia; a single example.

The type of this species was collected at Salisbury, Rhodesia, and is the only known specimen, with the exception of the one recorded above.

Manchester Memoirs, Vol. lvi. (1912), *No.* 3.

III. Intensive Study of the Scales of three Specimens of *Salmo salar.*

By Philippa C. Esdaile, M.Sc.,

Honorary Research Fellow in Zoology, University of Manchester.

(Communicated by Professor S. J. Hickson, D.Sc., F.R.S.)

CONTENTS.

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III. Intensive Study of the Scales of three Specimens of *Salmo salar.*

By Philippa C. Esdaile, M.Sc.,
Honorary Research Fellow in Zoology, University of Manchester.

(Communicated by Professor S. J. Hickson, D.Sc., F.R.S.)

(Received and read October 31st, 1911.)

During the past few years the scales of salmon have been studied with a view to proving that the age and rate of growth of the fish, as well as the occasions on which the fish has spawned, can be ascertained from the periodic growth of the rings or annuli by which the scales are built up. Mr. H. W. Johnston, in the 23rd Annual Report of the Fishery Board of Scotland, explains the method of reading salmon scales. His examination of a parr of known age has shown which part of the scale is formed during the early life of the fish in the river. Fish caught in the sea between the smolt and grilse stages show the beginning of the rapid summer growth after the fish had migrated to the sea. Scales taken from grilse caught in the river show the slower winter growth, after the broad formation caused by the rapid summer feeding, and this slower growth was again followed by rapid increase formed in the sea during the summer just before the fish was caught. Small spring fish show signs of rapid feeding on entering the sea, then the slower growth of the winter; following this, the broad formation during the second summer, and then at the periphery of the scale, a second period of slow feeding during the second winter spent in the sea. The scales of small summer or autumn fish show this same arrangement with the addition of a third period of rapid increase, varying in size according to the date of capture. The large spring fish show rapid and slow growths alternating three times.

Mr. Johnston proves all these results by examining the scales of fish which had been previously marked when they were migrating to the sea as smolts. He also proves that a fish which has entered the river for spawning purposes has a very distinct and indelible mark on its scales. Almost as soon as a spring or early running summer fish reaches the river, the scales begin to disintegrate at the periphery, and by the time the fish is a kelt a very considerable portion of the surfaces and periphery of the scales has disintegrated, and in most cases the scale has the appearance of being much worn and frayed. In the case of late running summer and autumn fish, this disintegration also takes place in salt water, and before the fish has entered the river. On returning to the sea the fish begins to feed again ; the new growth of the scale is regular and is in great contrast to the irregularities caused by this disintegration, so that a very clearly defined mark is made, which Mr. Johnston has termed the "spawning mark."

Herr Dahl confirms all Mr. Johnston's work, and shows that the marks on the scales of Norwegian salmon are formed in a similar manner to those on the scales of Scottish salmon. He made careful investigations as to the "spawning mark" and the extent of the degeneration of the scales while the fish are in the river before spawning. The rest of Herr Dahl's work on the salmon shows us in how many ways the knowledge of the age of the fish from its scales can help us in discovering more about the life-history of the fish. His work is full of most interesting results, and great thanks are due to the Salmon and Trout Association for arranging for the immediate publication of an English translation, which will be of great assistance to the numerous workers engaged on the study of the life-history of the salmon.

Before going further into previous work, it will be advisable to give names to the different parts of the scale, in order that misunderstanding may not occur. Already the terms "annual lines," "ridges," "rings," and "lines" have become confused. Although many descriptions of the scale have been given, one more is now added to that number for the purpose of introducing the names I propose to use. The scale is lamina-like, the internal side is smooth, but on the external surface there are inequalities which can be readily felt on passing a needle over the scale. On closer examination it will be found that the inequalities are caused by what have hitherto been called "lines" or "ridges," but which I shall term annuli (see photo of Scale A). These annuli are arranged in a roughly concentric manner from the centrum of the scale (C), and are formed chiefly on the anterior portion of the scale, which is enclosed in a pocket of skin, but also, to a very slight extent, on the posterior exposed portion. Examination with the low power of the microscope shows that the annuli are arranged in a definite manner, some far apart and others closer together. Those far apart are, according to Mr. Johnston, formed during the rapid growth of the fish in the summer, and those closer together during a time of slow increase in the winter. This formation of annuli far apart, together with the formation outside this of annuli more closely placed, was called by Mr. Johnston an "annual ring." For this name the word "Peronidium" is substituted, and it is used to indicate the growth which takes place in a complete summer and winter.

The annuli are very irregular. They branch frequently, giving off both long and short branches, and they are at very varying distances from one another. The summer and winter growths are not always clearly defined. The decrease in the rate of growth at the beginning of the winter is often very gradual, and therefore the annuli gradually become closer together, so that it is difficult to say where the summer growth ceases and the winter growth commences. Dr. Turnbull, writing in *The Field*, gives an account of his method of counting the annuli; he distinguishes between what he calls "main" and "duplicate" annuli, stating that the "main annuli may split or fork in the neighbourhood of the long axis to form duplicate annuli." This distinction, however, seems to be most unsatisfactory. The annuli are all so different. No two branches are alike, and there might be a score or more of cases on one scale only where a heated discussion might be held as to whether the annuli in question are to be called "main" or "duplicate." After distinguishing between these two kinds of annuli, Dr. Turnbull counts only the "main" annuli, and uses only these for the comparison of the scales from different fish. Mr. Johnston does the same thing, counting what he calls the "main stems" and not the "off-shoots." All investigators of the scales of fish state that as the fish grows, the size of the scale is increased, and annuli are formed at intervals. Each annulus then must show that growth has taken place, and growth must have taken place in a particular part where a so-called "duplicate" annulus is formed; and yet, according to some, this special kind of mark of growth is to be ignored. Surely this method renders the work almost useless when endeavours are being made to ascertain the age and rate of increase of the fish as indicated by the scales.

Hitherto the scales used for this study have been taken from what is known as the shoulders of the fish ; that is, from the area midway between the dorsal median line and lateral line, and between the dorsal fin and the operculum. The enumerations of the annuli were made, as Mr. Johnston tells us, " a little to one side or other of the long axis of the scale." (See *Diag.* 1, *Fig* 5.) So far, no systematic examination of scales from different parts of the same fish has been published. A systematic examination seems to be an essential preliminary to accurate work, for how can comparisons be rightly made of scales from different fish when the extent of variation on one fish is not known ? In order that this might be done, Mr. J. Arthur Hutton very kindly supplied a 10lb. fish caught in the nets of the estuary of the Wye on August 1st, 1910. From this fish scales were collected from fourteen positions, seven of which are shown in *Diag.* 1, *Fig.* 1, the other seven being corresponding positions on the right side of the fish. The number of annuli on one scale from each of the seven positions on the left side of the fish was ascertained, and measurements were taken of the distances from the centre to the periphery along both the long and short axis. In order that these results might be more accurate, a specially marked eye-piece was used. (See *Diag.* 1, *Fig.* 4.) The scales were cleaned in water and mounted with the internal side downwards. By this means, as all the scales are taken from the same side of the fish, comparisons can be made between the dorsal and ventral sides of the different scales. Placing the slide on the stage of the microscope so that the centrum of the scale came under the point on the marked eye-piece, which in the *Fig.* is called A, and the long axis (see *Diag.* 1, *Fig.* 5) along AB, calculations were made along the lines AB and AC, taking into account every annulus which crossed the lines on the eye-piece and making no distinction whatever between main or duplicate branches. By inverting the marked eye-piece, enumerations could be made along lines at 30° on both sides of the long axis.

This particular fish had, according to the reading of the scale put forward by Mr. Johnston, spent two years and a portion of a third year in the river, and two years and a portion of a third year in the sea, thus showing four peronidia and the beginning of a fifth (see *Diag.* 2). However, in registering the number and measurements of the annuli, the river growth has not been merged with that of the sea, but a new division has been made which is used for the portion of the third peronidium formed in the river. Conditions in the river are much more variable than those of the sea, and therefore, when considering the variations in the amount of growth which has taken place, it is advisable to carefully distinguish between the portions of the scale which have been formed in the sea or the river. By making this distinction the divisions of the scale do not correspond to the peronidia, and in the register of the enumerations and measurings the word "period" has been used. This would not be necessary if the young fish had migrated before there was any commencement of feeding during the early part of the third year in the river. The "periods" would then coincide with the peronidia and the word "period" be unnecessary. (See *Diag.* 3.)

Table 1 shows the results of the examination of the scales, one from each of the seven positions on the fish, and it is evident that there is a great amount of variation in the number of annuli on the various scales. It will be noticed that no two scales are alike in any one respect, except that from whatever part of the body they are taken they all have the same number of peronidia. The total number of annuli varies from 76 to 121, this range of variation being due not to variation in any one particular peronidium, but to variation in each peronidium. This great variation is not due to a casual variation of the scale, but is caused, to some extent, as the figures show, by definite local differences. That is to say, speaking generally, *the number of annuli in each peronidium increases from the head to the adipose fin, on both dorsal and ventral sides of the lateral line, and then decreases again towards the tail.* It would be of very great interest to study more scales from each of these seven positions in order to ascertain whether these differences were merely abnormalities of the particular scales which had happened to be taken for examination or whether other scales from the same positions would also show the same variations.

While looking out and preparing the material for this test it was noticed that the scales from different parts of the body differed very much in size and shape. Thus it was found that scales from position (1) approximated generally to one type, while those from (2), as a whole, differed from those from (1), and could be called type 2. This was found to be the case with each set of scales from the various positions on the fish ; there were as many types as positions from which scales were examined. These types are in some cases so distinct that after a little practice one can pick out the scales from the different positions without referring to the numbers of the slides.

There is always great difficulty in making up these sets of scales. About thirty scales were taken from each position on the fish, but on examination it was frequently found that twenty or more had imperfect centres, so that there might not be even three scales from any particular position, which were useful for purposes of examination. Very often three or four of the annuli at the centrum seem to be missing, and these scales were discarded as imperfect. It was most disappointing, therefore, to find that on the fish from which scales had been taken from fourteen different positions, neither set of scales from one side or the other was complete enough for careful examination, and therefore we cannot verify the results obtained from the one scale from each position. Positions (4) and (8) (See *Diag.* 1) are the most difficult regions from which to obtain useful sets of scales.

Again, through the kindness of Mr. Hutton, further work on this part of the scale problem was rendered possible. Mr. Hutton collected scales from seven positions of a 17lb. fish. (See *Diag.* 1, *Fig.* 2.) This was a freshly run female fish caught on February 2nd, 1911, at Hampton Bishop, on the Wye; its length was 35″ and its girth 18″. The seven sets of scales were mounted in the manner already described, and the number of annuli per period was ascertained at the long axis and at 30° to the left and right; and the length in millimetres of each period was also measured along the long axis. Wherever possible, ten scales were examined from each position. From position (4) however, only three scales were perfect enough to use. The averages of the results obtained from so small a number are not very trustworthy evidence, but they are all that is at hand for the present. The averages of the results obtained are to be found in Table 2. The great variations in the number of annuli and in the lengths per period are at once noticed. But what is most interesting, though it cannot be shown because of lack of space, is the variation of the scales from each position. Taking, for example, the scales from position (2), the total number of annuli on the long axis varies from 96-101, at 30° to the left of the long axis from 97-107, and at 30° to the right of the long axis from 89-101. The extent of variation in the length of the scales on the long axis is ·61 mm. Taking another example in the scales from position (3), the total number of annuli varies from 105-118 on the long axis and from 109-118 on the left of the long axis, and from 108-122 on the right of the long axis, while the maximum and minimum lengths of the scales differ as much as 1·03 mm.

Turning again to the examination of the averages of the results, it is to be noticed that the total number of annuli on the scales, with few exceptions, increases from position (1) to (3), and decreases from (3) to (4)—that is, from the head to the adipose fin, and from the adipose fin to the tail. The Table indicates that a similar variation is found also in the total lengths of the scales and in the lengths per period. As has been previously pointed out, this variation occurs in each peronidium and not in any particular one. The scales taken from the ventral side of the fish also have an increasing number of annuli per period, from the head to a position on a level with the adipose fin; and in the same way this increase is in each period, and the length of each period is greater from the head to the adipose fin. There are irregularities in some cases, but it can be said that there is some definite arrangement.

A further comparison of the results obtained indicates that there is another method in which the scales are arranged. It will be noticed that positions (1), (2) and (3) are exactly above positions (5), (6) and (7); and comparing the figures obtained from positions at the same distance from the head, it is clear that in nearly all cases the scales on the ventral side of the fish are longer and have more annuli per period than those from a corresponding position on the dorsal side. (See *Graphs* 1 and 2).

As it was thought desirable to obtain data from another fish, Mr. Hutton obtained more scales—in this case from a 26lb. fish caught at Hampton Bishop, 10th March, 1911. It was a male, freshly run, measuring 41½" in length and 20½" in girth. The results from this fish do not appear to be as regular as those obtained from the 17lb. fish; but on the whole it can be said that the same general arrangement is followed in spite of the many irregularities. The records of the scales from the 26lb. fish are to be found in Table 3 and *Graphs* 3 and 4.

Endeavours have been made to ascertain whether this increase and decrease in the number of annuli per period can be expressed as a definite ratio and follow some rule. One might have imagined that some mathematical formula could have been found to express the variations, but, so far, I can find no connection between the results, and no formula which will help to make clearer what now appears to be a chaos of figures. For this purpose the averages of the three series of records, on the long axis and at 30° to the left and right, were obtained (see Table 4 A). From this Table it is quite easy to ascertain the rate of increase and decrease in the number of annuli which is shown in Table 4 B. On examining these figures it will be seen that there seems to be no definite rate of increase and decrease either on the dorsal or ventral side. There is no constant variation in the number of annuli in the different periods of scales from the same position; there is no definite variation in the number of annuli in the periods of scales from different positions. And comparing the results of the two fish there seems to be no law or theory which could be applied to both.

Dr. Turnbull in his article in *The Field* makes a short reference to the study of scales taken from different parts of the same fish.

> "The scales were found to increase in size and to become more elongated from the head towards the tail, and there is a corresponding increase in the number of the main and duplicate ridges."

But beyond this there is no other reference. I have already discussed the length of the scale and the number of annuli. The relative sizes of the scales can be seen from *Diagrams* 4 and 5. These were drawn from the scales with a camera lucida, and the drawings were reduced with a pantograph. They give some idea of the sizes of the scales from various parts of the body. Each scale is typical of the particular position, and therefore can be used to some extent as a guide to the width of the scales and their shape. From these cases it would seem that the scales increase in breadth as well as length from the head to the adipose fin and again decrease from this point to the tail.

General Conclusions.

On comparing the Tables, the most remarkable fact one notices is the variation both in the number of annuli and in the measurements of the scales, which, in many cases, must have been taken from the same square inch. The measurements are additional proof that the surface dimensions of the scales cannot be used as a criterion of the age of the fish.

With regard to the annuli a question that might be asked is, Can any conclusions be drawn from the number of annuli in each peronidium? At present it would be rash to say that any definite number of annuli are formed in a month or that any definite number are formed in the winter or summer or even during a year. If the number of annuli were ascertained and then divided by a definite number, as Mr. Mallock suggests, a curious state of affairs would arise, namely, a different age for the same fish would be shown by many of the scales, even when taken from the same position. There is no actual proof that a large number of annuli in each peronidium indicates that the fish has had good feeding grounds and a favourable environment. It is what would be expected, but it is not borne out by the facts. If this were the case, the difference in the number of annuli on the scales of different fish would be to some extent explained, but not the variations in the scales of the same fish.

Turning to the Tables, it will be seen that it is not an invariable rule that the long axis of the scale has more annuli than those lines at 30° on each side of it. In fact, in the majority of cases, both in the total numbers and in the numbers per period, the long axis has fewer annuli than lines at 30° to the left and right. By comparing the results obtained from the left and right sides of the long axis, it is very astonishing to find how few cases there are where the numbers are equal. Sometimes in one set of scales one side will have, in each period, more annuli than the other ; while in some other cases in one period the left side will have more annuli, and in other periods the right side will have more. The case when one side has, in every period, more annuli than in the other, can be accounted for by the fact that in certain positions on the fish one side of the scales seems to grow more than the other. The whole study of these scales has shown the great irregularity in every particular. This shows that much caution should be used in saying that the scales show this or that. Much more experimental work has yet to be done to ascertain what conditions influence the growth of the scales and the formation of the annuli. It cannot only be additional food which causes increase in the number of annuli, because in the same fish there is such great variation in this respect.

Another very important point which should be specially noticed in the results is that the scales to be used for the comparison of different fish should all be taken from very definite and restricted areas. If care is not taken in this respect, variations in the scales of the individual will greatly hinder true comparisons being made of the scales from different fish.

Summary.

The special points which are brought out in this paper are as follows :—

I. A great variation in the number of annuli and in the lengths of the scales taken from different parts of the same fish is clearly indicated. This was found on each of three fish, but the results obtained seem to be in no way correlated.

II. It is to be noticed that in the three fish examined the number of annuli in each peronidium increases from the head to the adipose fin, and then diminishes towards the tail. A similar increase and decrease is found both on the dorsal and ventral sides of the lateral line.

III. In a comparison of scales taken from positions at corresponding distances from the head on both the dorsal and ventral sides of the lateral line, it is seen that, as a general rule, the scales on the dorsal side have fewer annuli in each peronidium than the scales from the ventral side.

IV. After carefully examining some hundreds of scales I can find no definite or trustworthy distinction between what have been called "main and duplicate annuli." The annuli branch towards the head and towards the tail, near the long axis or on a level with the short axis (*Line* AE., *Diag.* 1, *Fig.* 4). Taking all this into account, I find it impossible to recognise any distinction between different types of annuli.

This is to be looked upon as the beginning of a long piece of work. What I should like to have done, and what I still hope to do, is to carefully examine and measure a whole line or lines of scales from the head to the tail, and also lines from the dorsal to the ventral side, taken at different distances from the head. From this it would be seen, whether the increase in size and in the number of annuli is gradual and comparisons could also be made of scales which were actually found next to one another and not merely of those which have been roughly scraped off from certain places.

No hasty conclusions must be accepted, and it must not be thought that because this arrangement has been found in three fish it is necessarily present in all. It must be remembered that only 60 to 70 scales from each fish have been examined and measured, and the many hundreds of scales on one fish should not be judged by what is found in about sixty taken at random. It is, however, most probable that this arrangement is to be found in all salmon, though whether what now appear to be irregularities will eventually prove to be definite variations can only be shown by further research.

I must point out that this paper in no way contradicts the general truth of the Scale Theory, as applied to the salmon, worked out by Mr. Johnston and others. Every scale with a perfect centrum, no matter from what portion of the body it be taken, will more or less clearly indicate the age and growth of the fish.

I should like to express my thanks to Mr. J. Arthur Hutton for providing me with the necessary material and for his frequent visits to the Manchester University, where the work is being done, aiding me with advice, help, and information. I have also to express my indebtedness to Professor S. J. Hickson and Dr. J. Stuart Thomson, who have supervised the work, and who have always been ready to give advice, and to Miss Adamson, who translated Herr Dahl's paper for me in order that I might know about his work without waiting for the publication of the English translation.

TABLE NO. I.

AVERAGES OF THE RESULTS OBTAINED FROM THE SCALES FROM THE SEVEN POSITIONS OF THE 10LB. FISH, CAUGHT AUGUST 1ST, 1910.

Number of Position.	Total number of Annuli.			Number of Annuli in each period on the Long Axis and 30° to the Left and Right.																		Length of Scale in Millimetres.		
				1st.			2nd.			3rd.			4th.			5th.			6th.				Short Axis.	
	Long Axis.	Left.	Right.	L. A.	L.	R.	L. A.	L.	R.	L. A.	L	R.	L. A.	L.	R.	L. A.	L.	R.	L. A.	L.		Long Axis.	Left.	Right.
1	—	98	—	16	16	15	18	17	18	5	4	5	25	25	23	—	32	—	—	4	—	4·0	2·96	2·24
2	99	93	100	11	10	11	15	15	16	4	4	4	28	25	27	37	35	37	4	4	5	4·66	3·41	3·49
3	121	119	119	21	20	20	21	21	21	5	6	6	29	27	28	40	40	40	5	4	4	5·2	4·07	3·78
4	—	—	96	13	13	13	17	16	17	6	6	6	25	25	25	27	29	30	—	—	5	3·52	3·04	3·04
5	117	108	109	13	17	19	20	21	18	6	5	4	29	27	27	37	32	36	7	6	5	4·4	3·36	3·36
6	107	105	—	12	12	12	16	15	16	4	5	4	30	29	28	37	37	36	8	7	0	5·61	3·58	3·99
7	76	70	77	5	6	6	12	12	13	3	3	3	25	21	24	27	25	27	4	3	4	3·34	1·99	2·20

A POSITIONS OF THE 17LB. FISH.

Nu Pos	R.	Length of each period in Millimetres measured on the Long Axis. 1st.	2nd.	3rd.	4th.	5th.	6th.	Total length in m/ms.
	6·6	·17	·33	·16	1·26	1·97	·51	4·40
	8·5	·23	·41	·17	1·65	2·02	·46	4·94
	9·1	·37	·56	·18	1·69	2·15	·48	5·06
	9·0	·27	·48	·17	1·06	1·60	·26	3·84
	9·8	·22	·48	·21	1·64	2·13	·64	5·32
	11·5	·25	·52	·21	1·80	2·44	·85	6·07
	11·4	·40	·61	·24	1·95	2·30	·59	6·09

7·5 | 4·1 | 4·1 | 1·1 | 4·8 | 6·6 | 27·9 | 7—8

A OSITIONS OF THE 26LB. FISH.

R.	Length of each period in Millimetres measured on the Long Axis. 1st.	2nd.	3rd.	4th.	5th.	6th.	Total length in m/ms.
·5	·21	·36	·14	1·54	2·08	1·26	5·68
·1	·30	·46	·16	1·78	1·98	1·08	5·76
·1	·46	·60	·18	1·71	2·10	·86	5·91
·5	·42	·54	·20	1·8	2·04	·88	5·88
·6	·28	·47	·18	1·66	2·21	1·53	6·33
·7	·31	·52	·20	1·98	2·47	1·45	6·93
·5	·49	·6	·22	2·10	2·46	1·20	6·07
·3	·31	·48	·17	1·46	1·73	·50	4·65

TABLE No. 2.

AVERAGES OF THE RESULTS OBTAINED FROM THE SCALES FROM THE SEVEN POSITIONS OF THE 17LB. FISH.

Number of Position.	Total number of Annuli.			Number of Annuli in each period on the Long Axis and at 30° to the Left and Right.																		Length of each period in Millimetres measured on the Long Axis.						
				1st			2nd			3rd.			4th.			5th			6th.									
	Long Axis	Left.	Right.	L.A.	L.	R	L.A	L.	R	L.A	L	R	L.A.	L.	R.	L.A	L.	R.	L.A.	L	R.	1st.	2nd.	3rd.	4th.	5th.	6th.	Total length in m/ms.
1	88·2	87·5	84·0	6·1	6·3	6·1	10·8	10·6	10·8	3·7	4·2	4·0	23·0	22·5	22·6	35·7	35·2	33·6	9·2	8·5	6·6	·17	·33	·16	1·26	1·97	·51	4·40
2	98·2	101·2	95·5	7·3	8·1	7·5	13·3	14·4	13·7	3·6	3·5	3·7	28·0	27·4	27·4	40·5	39·5	34·1	9·7	11·4	8·5	·23	·41	·17	1·65	2·02	·46	4·94
3	114·0	114·8	116·4	12·8	12·5	12·8	18·1	17·7	17·8	5·1	4·4	4·8	30·2	29·2	29·6	38·7	38·6	41·2	9·7	11·6	9·1	·37	·56	·18	1·69	2·15	·48	5·06
4	96·0	95·0	96	10·0	10	11	17	15	17	5·3	5·6	5·0	21·3	21·0	21·6	34·3	36·0	34·3	8·6	8·3	9·0	·27	·48	·17	1·06	1·60	·26	3·84
5	96·1	95·5	94·5	7·8	8·0	8·5	12·5	12·8	12·7	4·5	4·7	4·7	26·2	26·0	26·8	34·0	33·4	31·8	10·8	10·5	9·8	·22	·48	·21	1·64	2·13	·64	5·32
6	107·8	106·0	103·8	9·1	9·0	9·7	14·1	14·6	14·6	4·5	4·6	5·0	29·0	28·5	27·3	38·1	37·1	36·8	13·0	12·1	11·5	·25	·52	·21	1·80	2·44	·85	6·07
7	117·5	118·5	115·5	15·2	14·7	15·2	17·2	17·8	16·6	5·8	5·2	5·0	30·2	30·2	30·2	38·4	38·8	37·0	11·4	10·4	11·4	·40	·61	·24	1·95	2·30	·59	6·09

TABLE No. 3.

AVERAGES OF THE RESULTS OBTAINED FROM THE SCALES FROM THE EIGHT POSITIONS OF THE 26LB. FISH.

Number of Position	Total number of Annuli.			Number of Annuli in each period on the Long Axis and 30° to the Left and Right																		Length of each period in Millimetres measured on the Long Axis.						
				1st.			2nd.			3rd.			4th			5th.			6th									
	Long Axis.	Left	Right.	L.A.	L.	R.	L.A	L.	R.	L.A	L.	R.	L.A	L.	R.	L.A	L	R.	L.A	L.	R.	1st	2nd	3rd.	4th.	5th.	6th	Total length in m/ms.
1	104	107	105·6	10·2	10·6	10·0	12·6	13·3	13·1	3·7	3·8	4·0	20·4	27·0	26·4	32·2	32·2	30·9	20·9	20·3	19·5	·21	·36	·14	1·54	2·08	1·26	5·68
2	123·8	118·0	126·8	14·0	13·4	13·8	17·3	16·6	18·8	4·0	4·0	4·1	30·7	30·2	30·1	35·5	33·1	34·9	21·7	21·5	23·1	·30	·46	·16	1·78	1·98	1·08	5·76
3	137·7	146·3	138·1	20·2	21·2	19·2	21·7	22·8	21·8	5·1	4·8	5·0	31·5	32·3	31·2	39·0	40·6	38·6	19·2	24·6	22·1	·46	·60	·18	1·71	2·10	·86	5·91
4	130	131	111	20	20	18	21	21	19	5	5	6	30·0	29·0	29·0	33·0	33·5	29·5	20·0	22·5	13·5	·42	·54	·20	1·8	2·04	·88	5·88
5	112·4	111·2	115·6	11·4	11·2	12·8	14·4	15·4	15·6	3·6	3·8	3·8	28·0	28·4	28·8	32·3	32·8	32·1	22·0	20·8	22·6	·28	·47	·18	1·66	2·21	1·53	6·33
6	125·4	124·6	123·8	12·8	13·6	14·2	18·2	19·8	18·4	4·6	4·0	4·2	31·6	30·2	29·8	35·5	35·1	34·0	22·5	21·7	21·7	·31	·52	·20	1·98	2·47	1·45	6·93
7	140·0	143·0	150·0	22·0	20·0	25·0	22·5	23·0	24·0	5·5	5·0	5·0	33·7	31·7	32·5	40·0	39·5	40·5	19·5	23	24·5	·49	·6	·22	2·10	2·46	1·20	6·07
8	112·0	119·6	117·6	15·6	15·6	16·0	19·0	17·6	18·6	4·3	4·0	4·0	28·0	28·3	29·3	34·0	37·3	36·3	11·0	16·6	13·3	·31	·48	·17	1·46	1·73	·50	4·65

Table No. 4.

Average number of Annuli on the Scales from the different positions of the two Fish. "A."

17lb. FISH.

Position.	Total.	1st.	2nd.	3rd.	4th.	5th.	6th.
1	86·9	6·2	10·7	3·9	22·7	34·8	8·1
2	94·9	7·6	13·8	3·9	27·6	38·0	9·2
3	115·1	12·7	17·9	4·8	29·6	39·5	10·1
4	95·1	10·3	16·3	5·9	21·3	34·9	8·6
5	95·3	8·1	12·7	4·6	25·3	33·1	10·0
6	105·9	9·3	14·4	4·7	28·3	37·3	12·2
7	117·2	15·0	17·2	5·4	30·2	38·1	11·1
8	Not	recor	ded.				

26lb. FISH.

Position.	Total.	1st.	2nd.	3rd.	4th.	5th.	6th.
1	105·5	10·2	13·0	3·8	26·6	31·8	30·2
2	122·9	13·7	17·6	4·0	30·3	34·5	22·1
3	140·9	20·2	22·1	4·9	31·7	39·4	21·9
4	124·0	19·3	20·3	5·3	29·3	32·0	18·7
5	113·0	11·8	15·1	3·7	28·4	32·4	21·8
6	124·6	13·5	18·8	4·3	30·5	34·9	21·9
7	144·3	22·3	23·2	5·2	32·6	40·0	21·1
8	116·4	15·7	18·4	4·1	28·5	35·9	13·6

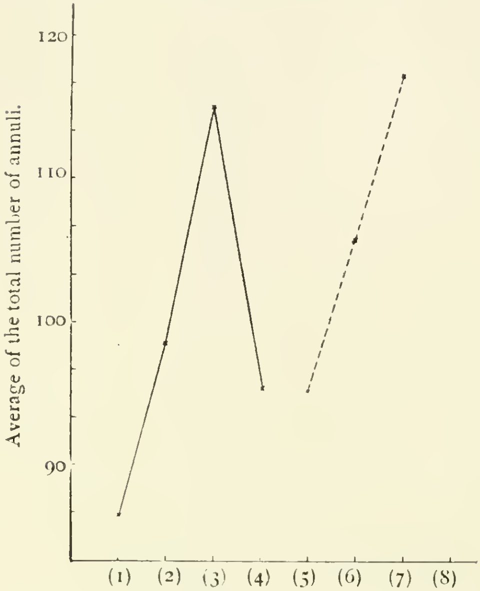
Showing the Increase and Decrease in the Number of Annuli on the Scales taken from the Different Positions of the two Fish. "B."

Position.	Total.	1st.	2nd.	3rd.	4th.	5th.	6th.
2—1	8·0	1·4	3·1	0	4·9	3·2	1·1
3—2	20·2	5·1	4·1	·9	2·0	1·5	·9
3—4	20·0	2·4	1·6	-1·1	8·3	4·6	1·5
6—5	10·6	1·2	1·7	·1	2·0	4·2	2·2
7—6	11·3	5·7	2·8	·7	1·9	·8	-1·1

Position.	Total.	1st.	2nd.	3rd.	4th.	5th.	6th.
2—1	17·4	3·5	4·6	·2	3·7	2·7	-8·1
3—2	17·8	6·5	4·5	·9	1·4	4·9	-·2
3—4	16·7	·9	1·8	-·4	2·4	·4	3·2
6—5	11·6	1·7	3·7	·6	2·1	2·5	·1
7—6	19·7	8·8	4·4	·9	2·1	5·1	-·8
7—8	27·9	6·6	4·8	1·1	4·1	4·1	7·5

GRAPH 1.

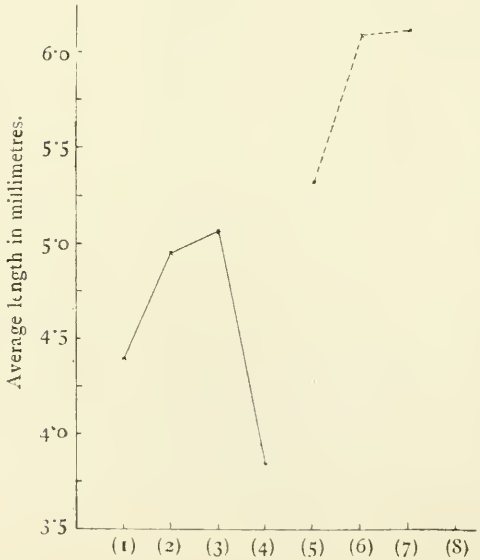
Showing the averages of the total number of annuli on scales from different regions of the 17lb. fish.



Numbers of the positions on the fish from which scales were taken.

GRAPH 2.

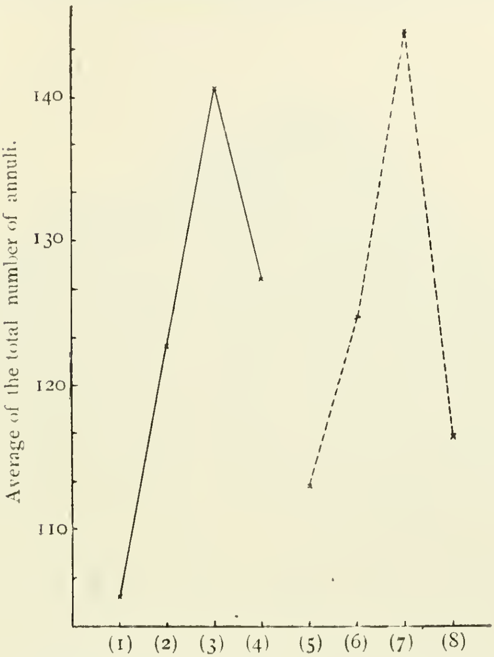
Showing the averages of the total lengths of Scales from different regions of the 17lb. fish.



Numbers of the positions on the fish from which scales were taken.

GRAPH 3.

Averages of the total number of annuli on scales from different regions of the 26 lb. fish.



Numbers of positions from which scales were taken.

GRAPH 4.

Averages of the total lengths of scales from different regions of the 26 lb. fish.

Numbers of positions on the fish from which scales were taken

REFERENCES.

CALDERWOOD, W. L. (1907). "The Life of the Salmon." Edward Arnold, London.

DAHL, K. (1910). "Alder og Vekst hos Laks og Œrret belyst ved Studiet av Deres Skjael." *Trykt i Centraltrykkeriet. Kristiania.*

—— (1911). "The Age and Growth of Salmon and Trout in Norway as shown by their Scales." Translated from the Norwegian. Published by the Salmon and Trout Association, London.

HUTTON, J. A. (1909). "Salmon Scales as Indicative of the Life-History of the Fish." Sherratt & Hughes, London.

—— (1910). "Salmon Scale Examination and its Practical Utility." Sherratt & Hughes, London.

JOHNSTON, H. W. (1904, '06, '07, '10).
23rd Annual Report of the Fishery Board for Scotland, Part II.
25th Annual Report, Part II.
26th ,, ,, ,, .
28th ,, ,, ,, .

MALLOCK, P. D. (1910). "The History and Habits of the Salmon."

TURNBULL, H. M. (1909). "The Scales of Salmon." *The Field*, December 11th, 18th and 25th.

× 15½.

Scale of 10lb. small Spring Cock Fish, caught in the Wye, April 7th, 1909. 30in. length, 15in. girth. This fish has spent two years in the river and two years in the sea, and was four years old. (*After Hutton.*)

Centrum	...	...	...	*C.*
Annulus	...	...	...	*A.*
Peronidium	...	...	...	*P.*

EXPLANATION OF DIAGRAMS.

Diag. 1.

Fig. 1. Showing the positions from which scales were taken from the 10lb. fish caught August 1st, 1910.

Fig. 2. Showing the positions from which scales were taken from the 17lb. fish caught February 2nd, 1911.

Fig. 3. Showing the positions from which scales were taken from the 26lb. fish caught March 10th, 1911.

Fig. 4. Diagram of the marked eye-piece which was used for the examination of the scales.

Fig. 5. Rough sketch of a scale showing the "long axis" = AB and the "short axis" = AE.

Diag. 2. Showing the river and sea growth of the scale. The portions of the scale formed in the summer and winter and the extent of the peronidia are also indicated.

Diag. 3. Showing the areas which have been used to show the variation in the number of annuli on corresponding areas of different scales. These areas, or periods, correspond to the peronidia, except the 3rd Period. This is part of the 3rd Peronidium, but having been formed in the river the number of annuli in that part has been separately recorded.

Diag. 4. Camera lucida drawings of scales, each being typical of those from the particular positions on the 17lb. fish. *Figs.* 1-7 show scales from Positions 1-7.

Diag. 5. Camera lucida drawings of scales, each being typical of those from the particular positions on the fish weighing 26lbs. *Figs.* 1-8 show scales from Positions 1-8.

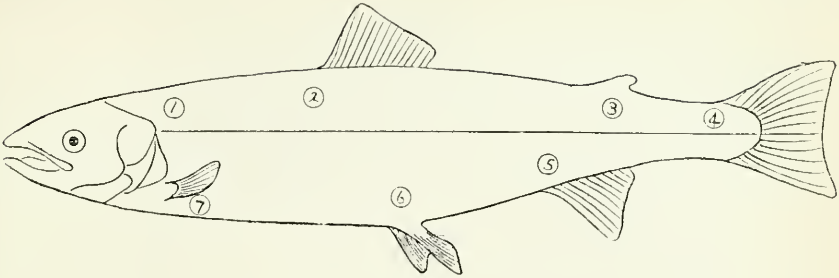


Fig. 1.

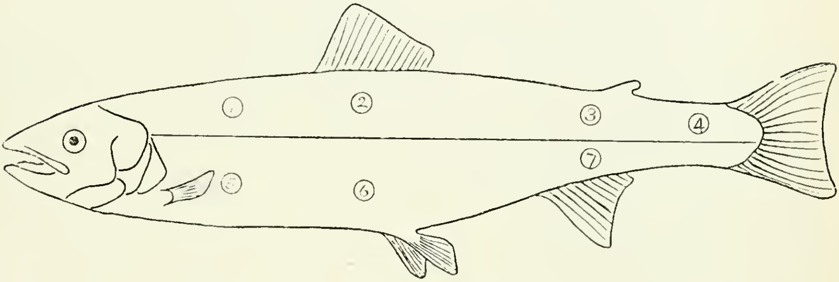


Fig. 2.

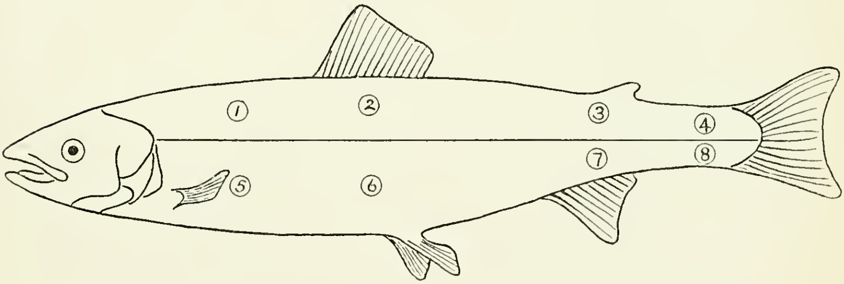


Fig. 3.

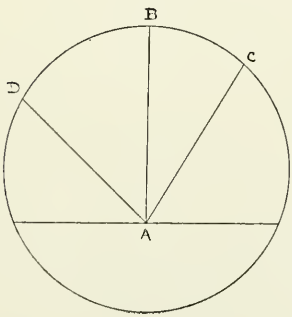


Fig. 4.

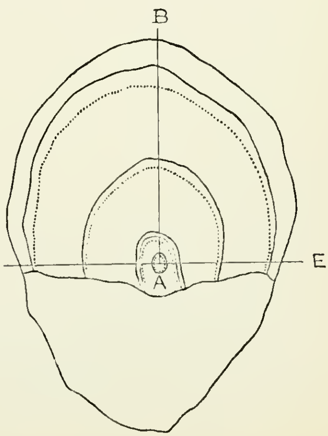
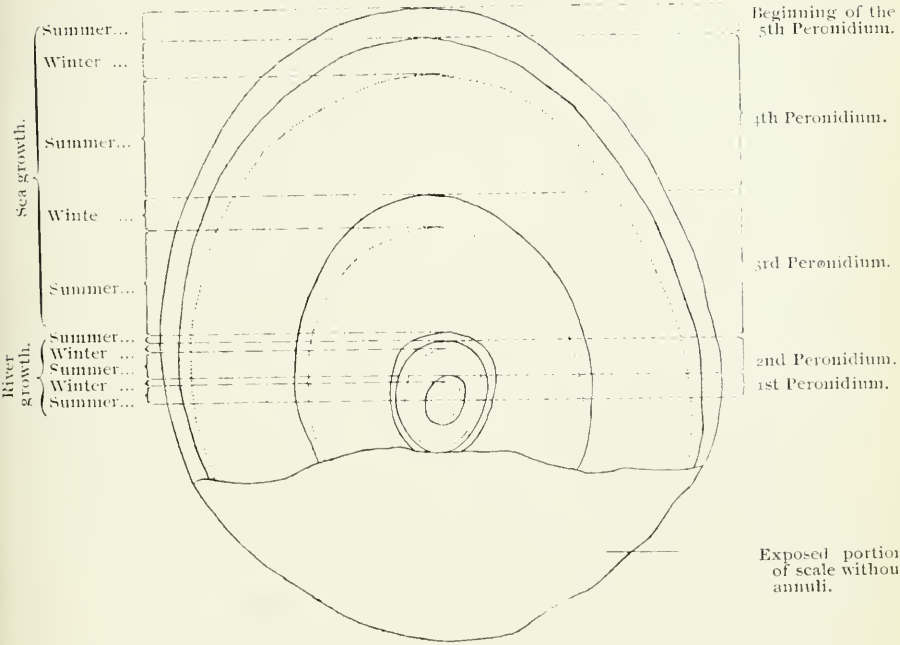


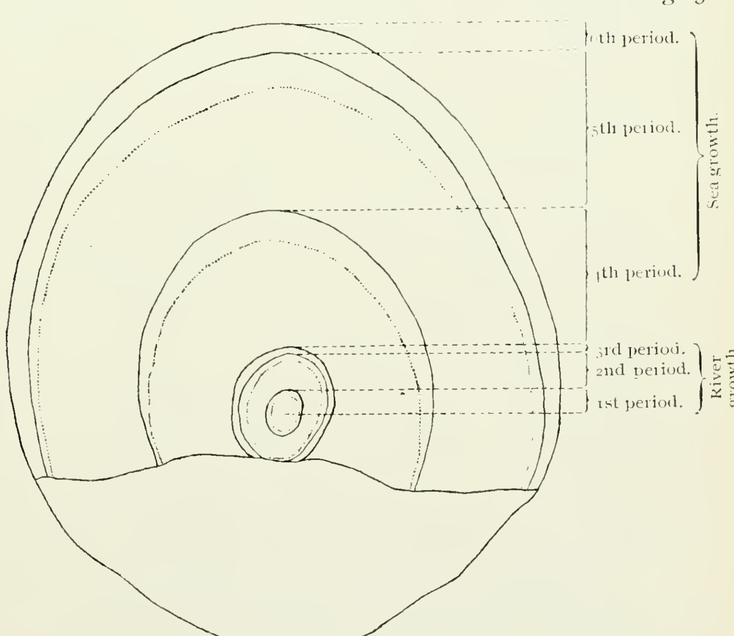
Fig. 5.

Diag. 2.



Summer...
Winter ...
Summer...
Winte ...
Summer...
Summer...
Winter ...
Summer...
Winter ...
Summer...
Sea growth.
River growth.
Beginning of the 5th Peronidium.
4th Peronidium.
3rd Peronidium.
2nd Peronidium.
1st Peronidium.
Exposed portion of scale without annuli.

Diag. 3.



6th period.
5th period.
4th period.
3rd period.
2nd period.
1st period.
Sea growth.
River growth.

Fig. 1

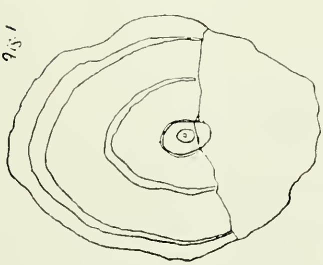


Fig. 2

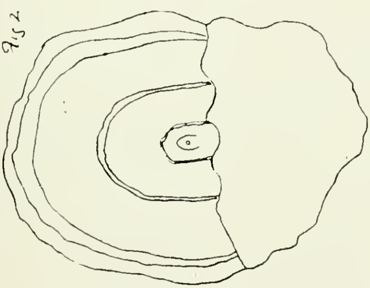


Fig. 3

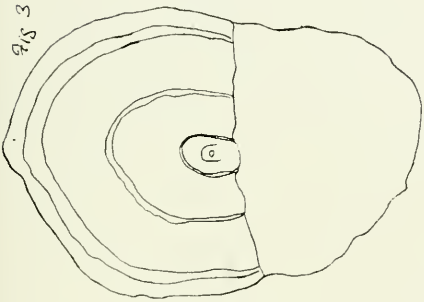


Fig. 4

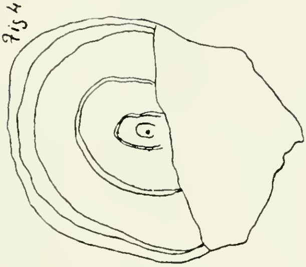


Fig. 5

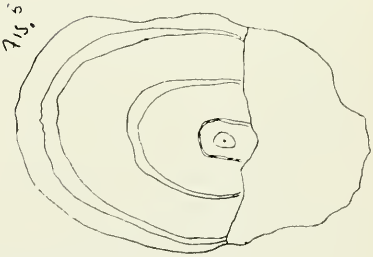


Fig. 6

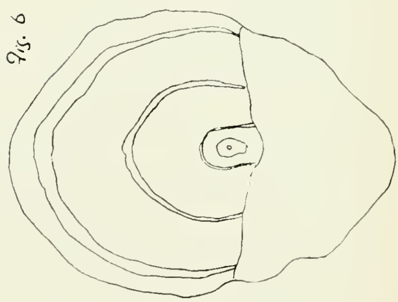
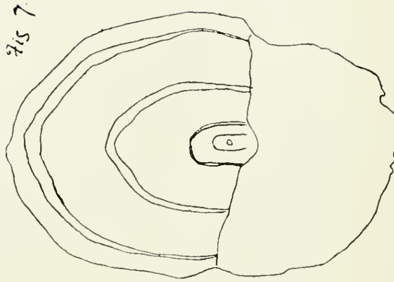
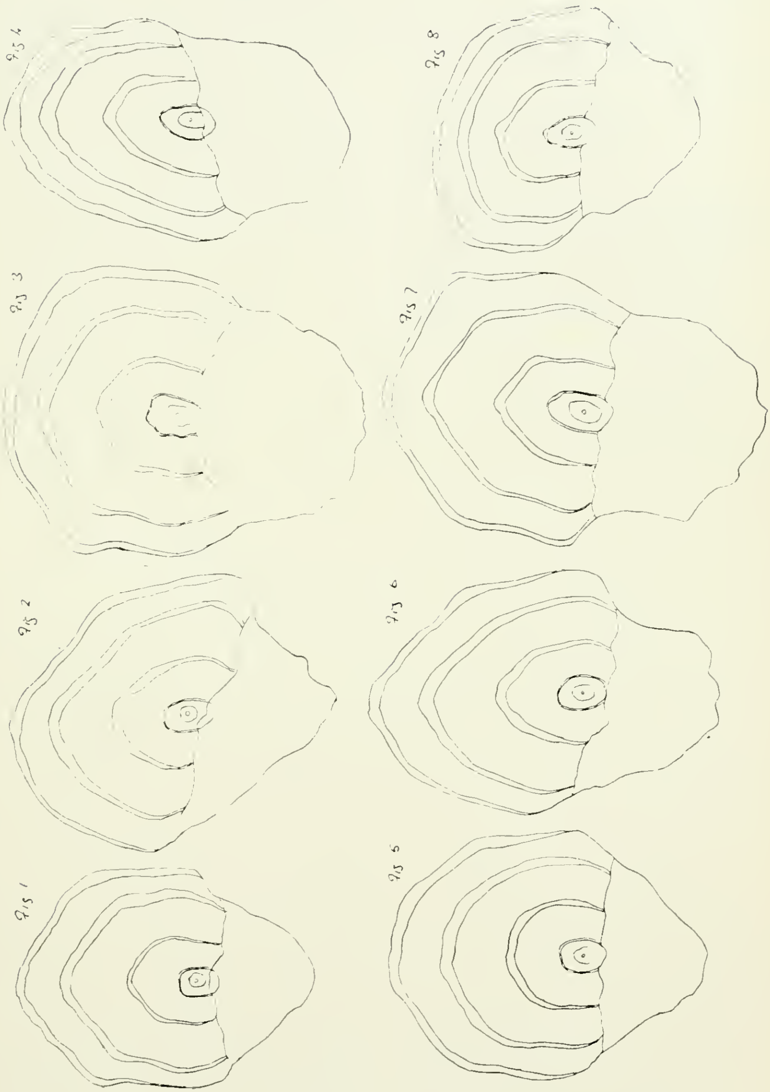


Fig. 7



NOTE.

Unfortunately no scales were taken from Position (8), and, therefore, no diagram can be given of a scale typical of this position.



Manchester Memoirs, Vol. lvi. (1912), *No.* 4.

IV. A Geometrical Treatment of Geodesic Torsion.

By LANCELOT V. MEADOWCROFT, B.A., M.Sc.

(*Communicated by R. F. Gwyther, M.A.*)

(*Received October 31st, 1911. Read November 14th, 1911.*)

In the first section of this paper is given an entirely geometrical treatment of the subject of geodesic torsion, the method adopted being one previously employed in demonstrating several theorems on lines on surfaces.[1] The remainder of the paper is devoted to some miscellaneous notes on lines on surfaces.

I. A Geometrical Treatment of Geodesic Torsion.

The conception of geodesic torsion is due to M. Bonnet, who defined it, under the name of second geodesic curvature, as the ratio borne to the element of the arc by the angle which the normal to the surface at one extremity makes with the plane containing the element and the normal at the other extremity. This definition does not lend itself easily to analytical expression or to geometrical treatment, and for the latter purpose at any rate is not so convenient as one involving only angles between lines, *e.g.*, the normals to the surface and the binormals of the curve. For these reasons I replace it by the following definition :—The ratio borne to the element of the arc by the difference between the angles made by the normals

[1] *Quarterly Journal of Pure and Applied Mathematics* (1909), No. 161.

to the surface at its extremities with the corresponding binormal (or osculating plane). The equivalence of the two definitions may be demonstrated by elementary geometry in the ordinary way, but the following proof by means of the spherical indicatrix is more satisfactory and convincing. Draw a unit sphere with O as centre, and from O draw lines parallel to the tangent, principal normal and binormal at one extremity of the arc ds, meeting the surface of the sphere in T, P and B respectively (*Fig.* 1). Let T', P', B' be their positions for the

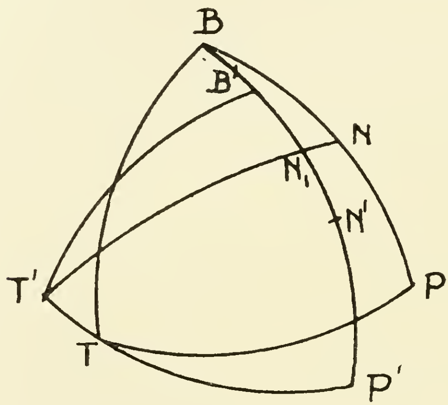


Fig. 1.

other extremity. The resulting figure is known as the spherical indicatrix, and it is a well-known property that TT' is tangential to $T'P'$ at T' and BB' to $B'P'$ at B'. Draw ON, ON' parallel to the two normals to the surface. N obviously lies in BP since $TN = \frac{1}{2}\pi$. Similarly N' lies in $B'P'$. Draw the great circle through T' and N and let it meet $B'P'$ in N Let $TT' = d\theta$ and $BB' = d\eta$.

Now ON' is parallel to the normal at one extremity of the arc and the plane $OT'N$ is parallel to the plane containing the element of arc and the normal at the other extremity. Hence if γ represents the geodesic torsion we have, by M. Bonnet's definition,

$$\gamma ds = N'N_1 = BN' - BN_1 = BN' - BN,$$

which proves the equivalence of the two definitions.

As a verification it may be noted that the new definition gives the correct result for a line of curvature or a geodesic. This is obviously so in the former case since $BN = BN'$.[2] In the latter case

$$\gamma ds = P'B - PB = BB',$$

since N coincides with P and N' with P'. Hence the geodesic torsion is equal to the ordinary torsion, a known result which justifies the use of the term. The definition includes as a particular case the definition of a line of curvature given in the former paper referred to.

The most important result in this subject is Laurent's theorem, the analytical statement of which is $\gamma = P - \frac{d\chi}{ds}$, χ being the complement of the angle between the osculating plane of the curve and the tangent plane to the surface at any point and P the ordinary torsion of the curve. This is easily proved by means of the spherical indicatrix. We have

$$\begin{aligned}\gamma ds &= BN' - BN = BB' + B'N' - BN \\ &= d\eta + \left(\frac{\pi}{2} - \chi - d\chi\right) - \left(\frac{\pi}{2} - \chi\right) \\ &= d\eta - d\chi,\end{aligned}$$

or

$$\gamma = P - \frac{d\chi}{ds}.$$

The same result may also be obtained by elementary geometry. Let PQ, QR, RS be three consecutive and equal elements of the curves, p, q and r their middle

[2] *loc. cit.*, p. 68.

points (*Fig.* 2). Draw the normal planes to the curve at p, q, r. Each of these planes meets the next in a polar line. Let the two polar lines meet in A. The normals to the surface at p and q will meet the polar line in a and

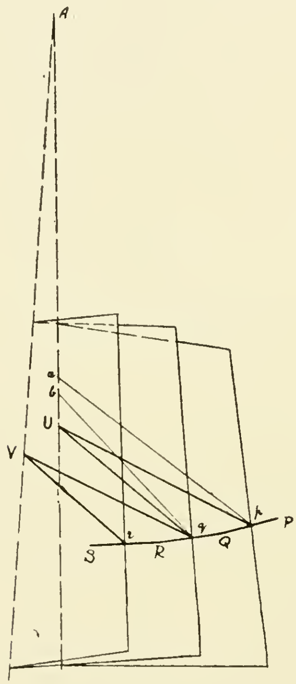


Fig. 2.

b (say). Let U, V be the centres of curvature at Q and R. Join Up, Uq, Vq, Vr.

The points A, U, V, q all lie in the normal plane at q, and are therefore coplanar. They are also concyclic since

$$A\hat{U}q = A\hat{V}q = \frac{\pi}{2}.$$

$$\therefore U\hat{A}V = U\hat{q}V.$$

Also Upq and Vqr are ultimately the osculating planes at Q and R and the polar lines are perpendicular to them.

$$\therefore d\eta = U\hat{A}V = U\hat{q}V.$$

Now

$$\gamma ds = U\hat{p}a - U\hat{q}b = U\hat{p}a + U\hat{q}V - V\hat{q}b$$
$$= U\hat{A}V + \chi - (\chi + d\chi)$$
$$= d\eta - d\chi, \text{ as before.}$$

A comparison of either of the above demonstrations, with the long analytical proof given by Laurent[8] will show the great superiority of the geometrical method. In practice nearly all the results on geodesic torsion are derived from Laurent's theorem, so that it is unnecessary to give any further examples, although it should be observed that most of them may be derived at once from the definition by means of the spherical indicatrix.

These views on geodesic torsion have been confirmed by Mr. R. A. Herman, Fellow of Trinity College, Cambridge, who points out that Laurent's theorem may also be derived by the method of rotations. If the curve and directions be referred to axes T, N and S, perpendicular to N in the normal plane (*Fig.* 1, S would be in NP produced so that $NS = \frac{\pi}{2}$), then these axes move by a spin which is the resultant of spins represented by vectors $d\eta$ along T', $d\theta$ along $B'a$ and $-d\chi$ along T', *i.e.*, $d\eta - d\chi$ along T, $d\theta \sin \chi$ along N' and $-d\theta \cos \chi$ along S'.

II. An Analytical Demonstration of Lancret's Theorem.

An analytical proof of this theorem does not appear to have been given, probably owing to the fact that the geometrical proofs are so simple. The analytical proof,

[8] *Traité d Analyse*, tome vii., p. 25.

however, although necessarily somewhat longer, is very elegant and affords an interesting application of the use of Serret's formulæ.

Let P (x, y, z) and Q $(x+dx, y+dy, z+dz)$ be two neighbouring points on a line of curvature. Let (l, m, n), (p, q, r), (λ, μ, ν), (u, v, w) be the direction cosines of the tangent, principal normal, binormal and normal to the surface at P respectively, and let the same quantities with increments be the direction-cosines of the corresponding lines at Q. Now the normals at P and Q intersect since the curve is a line of curvature.

$$\therefore x - \mu\rho = x + dx - (\mu + d\mu)\rho,$$

with two similar equations, ρ being the radius of curvature of the curve.

$$\therefore \frac{du}{dx} = \frac{dv}{dy} = \frac{dw}{dz} = \frac{1}{\rho} \quad . \quad . \quad . \quad . \quad . \quad \text{(i.)}$$

Now $\cos\chi = up + vq + wr$.

$$\therefore -\sin\chi d\chi = (udp + vdq + wdr) + (pdu + qdv + rdw)$$

$$= u(\lambda d\eta - ld\theta) + v(\mu d\eta - md\theta) + w(\nu d\eta - nd\theta) + (pdu + qdv + rdw),$$

by Serret's formulae,

$$= d\eta(u\lambda + v\mu + w\nu) - d\theta(ul + vm + wn) + \frac{1}{\rho}(pdx + qdy + rdz),$$

from (i.),

$$= d\eta \,.\, \cos\left(\frac{\pi}{2} + \chi\right), \text{ since } ul + vm + wn \text{ and } pdx + qdy + rdz$$

are both zero. $\therefore d\chi = d\eta$, which is Lancret's theorem.

III. To find Expressions for the Curvature and Torsion of a Line of Curvature.

An expression for the curvature of a line of curvature may be obtained by using a method given by Frost[4] for finding the position of the osculating plane. Let PR be

[4] Frost's "Solid Geometry," third edition, p. 285.

an element of the line of curvature and PQ an element of the perpendicular line of curvature. Let SR, SQ be lines of curvature through S. Let PHG, $QH'G$, RH and SH' be the normals to the surface at P, Q, R and S. Then PG, PH, QH' are ultimately the radii of curvature of the normal sections through PQ, PR and QS respectively. Let $PG=R'$, $PH=R$, $QH'=R+dR$. Now the

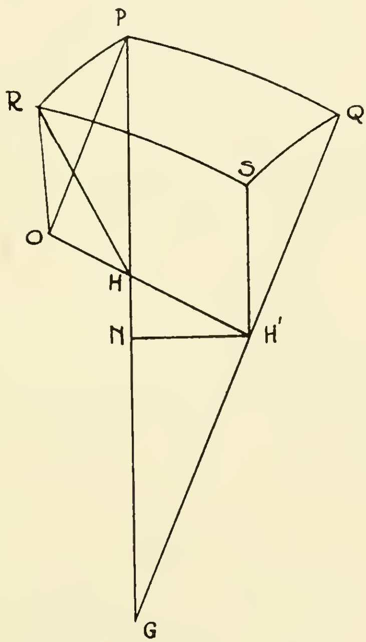


Fig. 3.

plane PGQ is obviously the normal plane of the curve PR at P, and since RH and SH' intersect the plane RHH' is the normal plane at R. These two planes intersect in HH', which is therefore perpendicular to the osculating plane POR. Draw $H'N$ perpendicular to PG.

Then

$$\tan\chi = \frac{HN}{H'N} = \frac{HN}{PQ} \cdot \frac{PQ}{H'N} = \frac{dR}{ds'} \cdot \frac{R'}{R'-R}.$$

$$\therefore \cos\chi = \left\{1 + \left(\frac{dR}{ds'}\right)^2 \frac{R'^2}{(R'-R)^2}\right\}^{-\frac{1}{2}}.$$

Now by Meunier's theorem

$$\cos\chi = \frac{\rho}{R}.$$

$$\therefore \rho = R\left\{1 + \left(\frac{dR}{ds'}\right)^2 \frac{R'^2}{(R'-R)^2}\right\}^{-\frac{1}{2}} \quad . \quad . \quad . \quad \text{(ii)}.$$

Again

$$\tan\chi = \frac{\sqrt{R^2-\rho^2}}{\rho}.$$

$\therefore$ the result may be expressed in the form

$$\frac{dR}{ds'} \cdot \frac{R'}{R'-R} = \frac{(R^2-\rho^2)^{\frac{1}{2}}}{\rho},$$

or

$$\frac{dR}{ds'} = \frac{R'-R}{R'\rho}(R^2-\rho^2)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad \text{(iii)}.$$

An expression for the torsion may be derived from Lancret's theorem by means of Meunier's theorem in much the same way.

We have

$$\cos\chi = \frac{\rho}{R}.$$

$$\therefore -\sin\chi d\chi = \frac{Rd\rho - \rho dR}{R^2}$$

$$\therefore (R^2-\rho^2)^{\frac{1}{2}} d\eta = \frac{\rho}{R} dR - d\rho$$

$$\therefore \frac{dR}{ds} = \frac{R}{\rho} \cdot \frac{d\rho}{ds} + \frac{R}{\rho\sigma}(R^2-\rho^2)^{\frac{1}{2}}, \text{ by Lancret's theorem} \quad . \quad . \quad \text{(iv)},$$

which gives σ when ρ has been found..

These formulæ, as might have been expected, would in general give ρ and σ as very complicated functions of x, y, z.

IV. To find the Curvature and Torsion of any Curve drawn on a Sphere.

As an example of the use of the above formulæ they may be employed to determine the curvature and torsion of any curve on a sphere, since every curve on a sphere is a line of curvature. In this case the first formula breaks down, as we should expect, since we must express in some way the orientation of the curve. The direct calculation of the curvature, however, can be made very briefly by means of a simple device. Let (x, y, z) and $(x+dx, y+dy, z+dz)$ be the coordinates of two neighbouring points of a curve on a sphere of unit radius and let (θ, ϕ), $(\theta+d\theta, \phi+d\phi)$ be their angular coordinates. Let the curve cut the meridian at an angle ω.

Then $$\cos\omega=\frac{d\theta}{ds},\quad \sin\omega=\sin\theta\frac{d\phi}{ds} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(v)}.$$

Now $x=\sin\theta\cos\phi$, $y=\sin\theta\sin\phi$, $z=\cos\theta$. Hence if (l, m, n) be the direction-cosines of the tangent line at (θ, ϕ) we have

$$\left.\begin{aligned} l&=\cos\theta\cos\phi\frac{d\theta}{ds}-\sin\theta\sin\phi\frac{d\phi}{ds}=\cos\theta\cos\phi\cos\omega-\sin\phi\sin\omega,\\ m&=\cos\theta\sin\phi\frac{d\theta}{ds}+\sin\theta\cos\phi\frac{d\phi}{ds}=\cos\theta\sin\phi\cos\omega+\cos\phi\sin\omega,\\ n&=-\sin\theta\frac{d\theta}{ds}=-\sin\theta\cos\omega, \end{aligned}\right\}\text{from (v).}$$

$$\therefore\frac{dl}{ds}=-\sin\theta\frac{d\phi}{ds}\cos\theta\cos\omega+\cos\phi\frac{d}{ds}(\cos\theta\cos\omega)$$
$$-\cos\phi\frac{d\phi}{ds}\sin\omega-\sin\phi\cos\omega\frac{d\omega}{ds},$$

$$\frac{dm}{ds}=\cos\phi\frac{d\phi}{ds}\cos\theta\cos\omega+\sin\phi\frac{d}{ds}(\cos\theta\cos\omega)$$
$$-\sin\phi\frac{d\phi}{ds}\sin\omega+\cos\phi\cos\omega\frac{d\omega}{ds},$$

$$\frac{dn}{ds}=-\cos\theta\frac{d\theta}{ds}\cos\omega+\sin\theta\sin\omega\frac{d\omega}{ds}.$$

On squaring and adding it is obvious by inspection that a large number of terms vanish or coalesce, and we easily find

$$\frac{1}{\rho^2} = \cos^2\theta \sin^2\omega\left(\frac{d\omega}{ds}\right)^2 + \sin^2\theta\sin^2\omega\left(\frac{d\omega}{ds}\right)^2 + \cos^2\omega\left(\frac{d\omega}{ds}\right)^2$$

$$+ \sin^2\theta\cos^4\omega + \frac{\sin^4\omega}{\sin^2\theta} + \sin^2\omega\cos^2\omega\cot^2\theta + \cos^2\theta\cos^4\omega$$

$$+ 2\sin\omega\cot\theta\frac{d\omega}{ds} + 2\sin^2\omega\cos^2\omega$$

$$= 1 + \left(\frac{d\omega}{ds} + \sin\omega\cot\theta\right)^2 = 1 + u^2 \text{ (say)}.$$

$$\therefore \frac{1}{\rho^2} = 1 + u^2 \quad \text{(vi).}$$

Substituting in (iv) we find

$$\frac{1}{\rho^2\sigma} = \frac{du}{ds} \text{ or } \sigma = (1+u^2)\Big/\frac{du}{ds} \quad \text{(vii.)}$$

This method possesses, I think, some advantages in point of directness over the method of moving axes more usually followed, besides avoiding the use of somewhat confusing figures. It should be remarked that for a sphere the equation (iv) reduces to the form

$$1 = \rho^2 + \sigma^2\left(\frac{d\rho}{ds}\right)^2.$$

This merely expresses that the radius of spherical curvature is unity or in other words that the curve lies on a sphere of unit radius.

V. TWO THEOREMS ON SKEW SURFACES.

The two following theorems do not appear to have been previously enunciated although they are simple generalisations of known theorems and can be deduced in a number of ways.

i. "The points along a generator of a skew surface at which the tangent planes are inclined at a given angle trace out two homographic rows of points."

ii. "The tangent planes also trace out homographic pencils."

It is well known that the anharmonic ratio of any four points on a generator of a skew surface is equal to the anharmonic ratio of the tangent planes to the surface at these points, so that the second theorem follows at once if the first is established. This can be done by proving it to be true for a hyperboloid, since a hyperboloid can be drawn to touch any skew surface along a generating line. If the generator G be taken as axis of x its equation will be

$$b\,y^2 + c\,z^2 + 2f\,yz + 2g\,zx + 2h\,xy + 2w\,z = O.$$

Let G' be the consecutive generator and OO' the shortest distance between G and G'. Let O, the point where the line of striction crosses the generator, be the origin, OO'

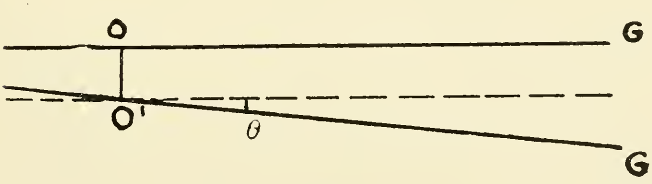


Fig. 4.

the axis of y and the normal to the surface at O the axis of z.

The generators through any point are

$$\left.\begin{aligned} \lambda(cz + 2fy + 2gx + 2w) &= 2hx + by \\ z &= -\lambda y \end{aligned}\right\} \quad . \quad . \quad . \quad \text{(viii)},$$

and

$$\left.\begin{aligned} \lambda'(cz + 2fy + 2gx + 2w) &= y \\ z &= -\lambda'(2hx + by) \end{aligned}\right\} \quad . \quad \text{(ix)}.$$

Then Ox is the generator for which $\lambda' = O$. For G' λ' is very small.

The equation of $O'G'$ is

$$\frac{x}{1} = \frac{y - 2w\lambda'}{2g\lambda'} = \frac{z}{-2h\lambda'},$$

neglecting λ'^2.

$\therefore$ its direction-cosines are $a1$, $2g\lambda'$, and $-2h\lambda'$.

Those of G are 1, O, O.

$\therefore$ the direction cosines of OO' are

$$\frac{\lambda}{O} = \frac{\mu}{-2h\lambda'} = \frac{\nu}{-2g\lambda'}.$$

But $\lambda : \mu : \gamma :: O : 1 : O$ and $\therefore$ $g = O$.

$\therefore$ the equation of the hyperboloid is

$$by^2 + cz^2 + 2fyz + 2hxy + 2wz = O.$$

The tangent plane at (r, O, O) is

$$(x - r)O + y \,.\, 2hr + z \,.\, 2w = O,$$

or

$$y \,.\, hr + zw = O.$$

Similarly the tangent plane at (r', O, O) is

$$y \,.\, hr' + z \,.\, w = O.$$

If these planes are inclined at an angle δ we have

$$\frac{hr \,.\, hr' + w^2}{\sqrt{h^2r^2 + w^2}\ \sqrt{h^2r'^2 + w^2}} = \cos\delta.$$

$\therefore$ squaring we find

$$h^4r^2r'^2 + 2w^2h^2rr' + w^4 = \cos^2\delta(h^4r^2r'^2 + w^2 \,.\, \overline{h^2r^2 + h^2r'^2} + w^4)$$

$$\therefore \sin^2\delta(h^2rr' + w^2)^2 = \cos^2\delta(r - r')^2w^2h^2$$

$$\therefore \left(rr' + \frac{w}{h^2}\right)\tan\delta + (r' - r)\frac{w}{h} = O \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (x)$$

This form of relation between r and r' proves the theorem.[5]

If ϕ is the angle which the tangent plane at $P(r, O, O)$ makes with that at O it has been shown by Chasles that $r = \omega \tan \phi$, ω being the pitch of the screw by means of which one generator is moved into the position of the next, *i.e.* $\omega = \frac{d}{\theta}$, where $OO' = d$ and θ is the angle between G and G'. If this relation (which is not difficult to prove) is assumed we find

$$(rr' + \omega^2) \tan \delta + (r - r')\omega = O.$$

If we write $w = -1$ it is easily seen that $\omega = \frac{1}{h}$, so that this relation is identical with (x).

If $\delta = \frac{\pi}{2}$ we get $rr' + \omega^2 = O$, so that the points form a system in involution. This is a known theorem.[6]

[5] Russell's "Pure Geometry," p. 114.
[6] A. J. C. Allen, *Mess. of Math.*, vol. xii., p. 26.

Manchester Memoirs, Vol. lvi. (1912), *No.* 5.

V. Observations upon the Improvement of the Physique of Manchester Grammar School Boys during the last 30 years.

By Alfred A. Mumford, M.D.

(Received and read November 14th, 1911.)

The importance of taking periodical physical measurements of school children consists in the fact that they can be used to give an index of growth, not only of a group, but also of individual members of the group. They are necessary if we are to examine the forces which act on health during school days.

Taken together with other details of school advance, they serve as useful records in studying the individual. In a healthy body, growth of all the tissues:—muscles, bone, brain, takes place coincidently, though not necessarily in equal proportions.

The actual fact under consideration is that the boys at the Manchester Grammar School to-day, in growth of bodily framework, are 6 to 9 months ahead of their predecessors thirty years ago. I should like to make a few general observations on facts which influence bodily growth.

There is a natural variation of total growth due to difference of innate powers of different individuals. And there is also great variation between the powers of the separate tissues of the same individual, so that at first it looks as if all tissues do not grow together. Thus, one boy will have great power of muscular growth, another of bony framework, a third of brain power in excess of that of other tissues. In this way, therefore, each boy may be said to follow his own special law of growth.

Secondly, there is an artificial interference with growth, particularly in the case of early disease. Interference with the growth of one tissue, occurring as a result of disease at an early period of life (that is under 7 or 8 years of age), will generally affect other tissues as well. Boys backward educationally very frequently show actual delay of bodily growth, particularly during the years up to 14 or 15, as well as delayed brain development. This delay of development of tissues other than the brain, may afford definite evidence of early childhood disease which has materially affected tissue-growth of the brain, as well as of the special part in which delayed development is noticed. The careful search for visible signs of such early disease should therefore be an important part of medical examination, and very particular attention should always be paid to the history of health during the first seven years of childhood. By rigid enquiry we can often get definite history of ill-health which, at first, the parents themselves had forgotten.

Before we can determine whether natural variation or artificial influence is the cause of the change in physique we have noticed, we may consider what particular causes may have influenced the figures and determined the increase noted.

The possible influence of a racial change in the community in causing the improvement. Since different races have different powers of growth, the change in Manchester Grammar School boys might conceivably be due to a change of race. Thus, there might be an increased admixture of a taller Norse race with the smaller Iberic race that used to constitute a good deal of the population of Lancashire. It is difficult to estimate how far this has exerted much influence. One can only say that there is undoubtedly a very large Jewish admixture, and that the Jews racially are in childhood smaller than the English ; and although, in other respects, they develop somewhat earlier, about the ages of 13, 14, or 15, yet by 17 and 18 they begin to show definite falling-off, at a period when the English boy is still growing. I think, therefore, that any improvement in physique, due to admixture of the taller Norseman and Anglo-Saxon with the old Lancashire inhabitants, is probably counter-balanced by the influx of oriental races.

A change of personnel in school due to presence of boys of another social grade might influence the change. It is uncertain to what extent the boys of to-day are the sons of fathers who were themselves educated at the school, but there is little doubt that the majority of the boys of to-day still come from the same social grade. There is also clear evidence that the minority, coming from a slightly lower social level, is somewhat increased, so that if we are to consider the change in physical development to be largely the result of change of race, and only slightly determined by outward conditions, we should have to suppose that the section of the population, who sent their children to the Grammar School 30 years ago, has been replaced by a racially different, as well as by a physically stronger, section who send their boys there to-day. The simplest explanation seems to me to be that there is increased vigour of bodily growth in the whole community, extending through both upper and lower social strata.

Altered relative length of stay in the school of small-sized scholars and larger-sized, physically more robust non-scholars during periods of most active growth. One other change in personnel may be that boys of good physique who are not studying for scholarship, but are intended for commercial pursuits, and who are not subject to so much strain in school life, stay a year longer at school. Such boys of particularly good physique would help up the average. That this factor is a considerable one is, I think, indicated by the fact that the improvement in physique is not noticed among the scholars who stay after 17 years of age.

It is probably far more easy to depress bodily growth than to stimulate it ; and it is certain that the most potent external effect on growth is that which is exerted at the very commencement of life.

Among the stimulants to growth must be mentioned climate and fresh air, bodily activity and food.

1st. *Atmospheric conditions which influence climate.* Meteorological observations in Manchester and Salford go back as far as 1868, when Dr. Tatham was Medical Officer for Salford. Unfortunately these do not include estimation of the amount of sunshine, or the chemical or other analysis for impurities in atmosphere. I have not been able to find in these weather records any appreciable change of mean barometric pressure or mean temperature, but I am informed that the condition of the atmosphere as regards smoke and other impurities is immensely better than it was. Further, although there is no record of the amount of sunshine, yet a purer atmosphere, due to a material diminution in amount of smoke, must imply more of the sun rays permeating through it, if not to the extent of actual sunshine, yet sufficient to have influence on health. A high rainfall I do not regard as detrimental to health. In Manchester, at least, it is beneficial by washing the air and freeing it from germs, while the improved drainage has made the houses much drier. Buxton, with a high rainfall, has a particularly invigorating atmosphere, though it probably possesses a drier climate than Manchester by the rapid withdrawal of moisture from the atmosphere by winds, etc., and free drainage from the soil.

2nd. *Bodily activity.* There has certainly been much increased attention paid to the organisation of games, exercises, etc., in school life at Manchester Grammar School. The Gymnasium was extensively used in the earlier period with the definite endeavour to produce increased development of the chest and arms, and it is possible that the greater upper arm development of the earlier period is due to this. But I do not think that the general development of all parts of the body as carried out in the period covered by the earlier record was as good as that secured by the modified Swedish drill at present in use, which is compulsory to all boys, and is superadded to apparatus work which was the sole compulsory school exercise in the earlier period. Heavy dumb-bells are now abolished. Of all the physical measurements in adolescence, Weight is probably the most important since the muscles comprise 43 per cent. of the body weight. Increase in the total weight, therefore, implies increase in total muscular development. The school games are more general to-day, and one hour a week is given to all classes for out-of-door games. Open-air camps and longer hours of sleep in the better-organised homes, owing to lessened home-work, have, perhaps, also exerted an influence on the health of the boys. In fact, life to-day is probably more uniform and more hygienic in most directions.

3rd. *Diet.* As regards change in diet, meat, if not less in total amount, is perhaps less in proportion to other forms of food, and I think there is an increased proportion of cereals, fruit, etc., with, perhaps, an increase in the total bulk. This change is, I believe, a good one for adolescent growth, where excessive proportion of meat is distinctly harmful. The change could be carried too far. We need nitrogeneous as well as starchy and fatty foods.

4th. *Economic conditions* depending on the size of family may have some influence, as the families of to-day are certainly smaller than 30 years ago. I consequently append a table showing the number of children in 445 families, taken consecutively, from the latest arrivals in the school. There are, unfortunately no earlier records to compare with them :—

One child in family	90 cases,	*i.e.*, 20%.
Two children in family	100 cases,	,, 22%.
Three ,, ...	103 cases,	,, 23%.
Four ,, ...	60 cases,	,, 13%.
Five ,, ...	46 cases.	,, 10%.
Six ,, ...	21 cases,	,, 5%.
Over six ,, ...	25 cases,	,, 5%.
Total............	445	

Secondary Education is an economic problem as well as a pedagogic one. We have to consider how far parents are able to pay for the board and lodging of the children as well as for their education. With few in a family, the economic problem for the lower middle class is easier, and there may be a "natural selection" going on ; so that "only children," and boys where there are only 2 or 3 in the family, form a larger proportion of the school population than formerly. Boys belonging to smaller families may get better cared for than those who formerly came from larger families.

Among the forces depressing to growth are such diseases as produce poisons capable of continuing in the system for a long period, or which produce alterations in structure of important organs:—rheumatism, inflammation of pharynx and bronchi, and tuberculosis are examples of the first; rickets, enlarged tonsils, and adenoids are examples of the second. All these exert a harmful influence long after the disease which originated them has disappeared.

In my first series of medical examinations, consisting of about 250 boys, in recording the past medical history, I mainly paid attention to such illnesses of childhood as scarlet fever, rheumatism, and diphtheria, since these are generally acknowledged to exert an evil influence on growth, and only included measles when I found that there had been some accompanying inflammation of the lungs, etc. I found a larger proportion had suffered from such early childhood illness in those boys who had serious impairment in their vision than in the boys with clear vision; and so, in my next series of investigations, I determined to pay much greater attention to this matter. In the second series, I have only found two boys with defective sight in whom I could not detect evident signs of illness having occurred in the early years of childhood, or where I could not obtain from the parents a history of very severe illness having occurred during the first seven years of life. I do not claim that the early illness was the sole condition of defective sight, but I think it was a precipitating or magnifying cause, and if the illness had not occurred it is probable that the onset of defective sight might have been postponed, or at least its intensity lessened, which would have been of great benefit to the child at the period of life when wide range of vision is an all-important necessity for largeness of view.

Effect on scholastic attainments of early interference with growth owing to disease in early life. Our attention lately has been directed to the necessity of recognising that even in the middle classes attending Secondary Schools there are a certain number of boys who cannot progress at the same rate as the majority of their fellows. They offer quite a different problem to that of the mentally deficient, for some of them are capable of being useful and even able citizens. They fall one or two years, or even more, behind their fellows. When they are two years behind, and do not show any capacity to in any way catch up, we speak of them as retarded boys. Some of these boys may have been artificially retarded owing to their previous preparation having been inadequate. Some of them, though by no means all, come late to the school, say at 14 or 15, or even 16, and from lack of mastery of the elementary points essential to a Secondary Education, they cannot be placed with boys of their own age. It looks at first sight as if this might be purely a matter of bad preparation, but, on full enquiry at the medical examination, I have found that in the majority of cases on careful search there could be detected some evidence of early ill-health having occurred which was the cause of their retarded progress at the present or at a previous school. A certain small proportion of cases that can only be put down to bad preparation still exists, but it is a very small one, and, of course, a certain small proportion due to imperfect brain power.

It is easy to be misled as to the cause of retardation occurring in late arrivals to the school, say, when the boy has reached 15 or 16. He comes with a good bodily frame, a good record of character and intelligence, and it is quite easy to miss detecting the exact point where his development has been interfered with, and to think with an apparently fully grown physique we have an individuality unimpaired by early disease.

Physical growth may be influenced by damage to growing tissues caused by acute infectious diseases in early life. Of all tissues in the body the brain is, perhaps, the most sensitive to factors which impair or impede growth during infancy and early childhood, though I admit that the lungs and the chest are also very sensitive to injurious influences, particularly at a later period. If such advantageous conditions occur during the later growth of the boy that there is apparent disappearance of all the injurious factors which at one time influenced growth, innate vigour may re-assert itself, and we get the phenomenon of an exceptionally good physical build with an exceptionally delayed brain development—a man in frame, but a boy in mind. This is not uncommon. Some of the most marked instances of this condition I have found in boys who had suffered from chronic ear trouble, causing abscesses which spread to the bones of the skull, and interfering for the time being with the brain development. I am not sure how far the recovery will be complete in these cases. It certainly does not take place during school life.

It is very difficult to estimate the full extent of the ultimate damage done to the various tissues by the acute infections of early childhood. It is certain that these diseases prevail less extensively than was the case 40 to 50 years ago, and that among the middle classes, when they do occur, it is at a later period of life than when they occur in the lower classes of society. It is also certain that the intensity of their onset is affected by social conditions, so that they are more fatal when they occur in the slums than when they occur in more sanitary homes. It follows that the relation of incidence to mortality is smaller in the lower strata of society than in the higher, though the sequela may be more severe.

The mortality per thousand from these illnesses for a number of years is given in the Report of the Medical Officer of Health for Manchester for 1910, p. 181.

	Estimated Population.	Annual Death Rate per 1000 Living.				
		Small Pox.	Scarlat.	Diphtheria.	Measles.	Whooping Cough.
1871-1875	477,344	0·26	1·08	0·08	0 64	0·78
1876-1880	509,802	0·24	1·07	0·13	0·53	0·84
1881-1885	542,746	0·04	0·48	0·10	0·71	0·68
1886-1890	575,603	0·02	0·50	0·32	0·83	0·54
1891-1895	517,801	0·03	0·26	0·27	0·62	0·64
1896-1900	539,599	...	0·20	0·13	0·89	0·53
1901-1905	554·355	0·01	0·19	0·22	0·55	0·41
1906-1910	660,049	...	0·16	0·17	0·54	0·37

In order to compare the age incidence in two different classes of society, I have analysed the records of a number of children attending the Northern Hospital, Manchester, and compared them with the record cards of the last batch of boys entering the Manchester Grammar School.

The following are the results in percentages :—

PERCENTAGES—MEASLES.

	No. of children examin'd	No infection under ten.	Infection 0–2 years.	Infection 2–3 years.	Infection 3–4 years.	Infection 4–5 years.	Infection 5–6 years.	Infection 6–7 years.	Infection 7–8 years.	Infection 8–9 years.	Infection 9–10 years.
Hospital children of all ages ...	317	17·0	19·2	12·3	20·5	12·9	9·1	3·7	3·1	2·2	—
Hospital children of 11 and over	80	11·0	16·2	10·0	16·2	16·2	6·2	10·0	8·75	5·0	—
M. G. S. boys ...	169	24·2	7·1	7·1	11·8	14·1	6·5	6·5	13·6	4·7	4.1

PERCENTAGES—WHOOPING COUGH.

	No. of children examin'd	No infection under ten.	Infection 0–2 years.	Infection 2–3 years.	Infection 3–4 years.	Infection 4–5 years.	Infection 5–6 years.	Infection 6–7 years.	Infection 7–8 years.	Infection 8–9 years.	Infection 9–10 years.
Hospital children of all ages ...	240	55·0	10·0	11·6	7·2	8·0	3·6	1 6	1·6	1·2	—
Hospital children, of 11 and over	64	50·0	9·3	3·1	10·9	9·3	6·2	3·1	3·1	1·2	3·1
M. G. S. boys ...	192	65·5	1·5	2·0	7·4	9·3	2·0	4·7	4·1	2·0	1·5

PERCENTAGES—SCARLATINA.

	No. of children examin'd	No infection under ten.	Infection 0–2 years.	Infection 2–3 years.	Infection 3–4 years.	Infection 4–5 years.	Infection 5–6 years.	Infection 6–7 years.	Infection 7–8 years.	Infection 8–9 years.	Infection 9–10 years.
Hospital children of all ages ...	273	80·2	0·2	2·5	0·7	1·8	4·0	3·6	3·6	1·8	1·1
Hospital children over 11... ...	74	63·5	2·7	1·4	—	—	9·4	6·5	6·5	6·5	2·7
M. G. S. boys ...	192	88·3	0·5	0·5	1·5	1·0	2·0	2·0	3·1	0·5	0·5

PERCENTAGES—DIPHTHERIA.

	No. of children examin'd	No infection under ten.	Infection 0–2 years.	Infection 2–3 years.	Infection 3–4 years.	Infection 4–5 years.	Infection 5–6 years.	Infection 6–7 years.	Infection 7–8 years.	Infection 8–9 years.	Infection 9–10 years.
Hospital children of all ages ...	253	93·0	—	—	2·4	0·4	0·79	—	0·79	2·4	—
Hospital children over 11... ...	63	90·4	1·4	1·4	1·4	—	—	—	1·4	1·4	2·8
M. G. S. boys ...	192	95·8	—	—	0·5	0·5	0·5	1·0	—	1·0	0·5

In conclusion, in assigning the value to each of the factors, I am inclined to the opinion that the diminution of incidence of early infectious disease during the first period of childhood (*i.e.*, before the age of seven years) is one of the most potent factors which has produced the improvement that we have noticed.

SUMMARY OF DIFFERENCES IN PHYSICAL DEVELOPMENT OF THE BOYS AT THE MANCHESTER GRAMMAR SCHOOL DURING A PERIOD 1881-86, AS COMPARED WITH A PERIOD 1905-10.

Age.	Height in inches.			Weight in lbs.			Chest girth in inches.			Forearm in inches.			Upper arm in inches.		
	1881-86	1905-10	Difference	1881-86	1905-10	Difference	1881-86	1905-10	Difference	1881-6	1905-10	Difference	1881-86	1905-10	Difference
10–11	53·2	52·94	−0·26	65·3	65·69	+0·29	24·9	24·68	−0·22	7·63	7·61	−0·02	7·81	7·60	−0·21
11–12	54·38	54·99	+0·61	69·28	72·05	+2·77	25·21	25·38	+0·17	7·79	7·79	equal	7·99	7·91	−0·08
12–13	55·94	56·70	+0·76	74·4	77·3	+2·9	25·92	25·93	+0·01	7·96	7·99	+0·03	8·27	8·11	−0·16
13–14	57·77	58·84	+1·07	81·01	85·47	+4·46	26·72	27·05	+0·33	8·28	8·29	+0·01	8·63	8·49	−0·14
14–15	59·82	61·08	+1·26	89·99	95·15	+5·16	27·71	28·17	+0·46	8·63	8·69	+0·06	9·1	8·97	−0·13
15–16	62·16	63·4	+1·24	101·41	105·9	+4·49	29·26	29·56	+0·30	9·08	9·09	+0·01	9·67	9·48	−0·19
16–17	63·84	65·35	+1·51	109·65	117·9	+8·25	30·06	30·91	+0·85	9·413	9·53	+0·117	10·19	10·13	−0·06
17–18	65·88	66·47	+0·59	119·36	124·84	+5·48	31·3	31·85	+0·55	9·80	9·79	−0·01	10·76	10·47	−0·29

A plus sign indicates an improvement. A minus sign a deterioration. Averages only are compared. Ages 9-10, 18-19 and 19-20 are left out. as the figures are too few to afford very reliable results. These figures are to be found in the detailed analyses.

HEIGHTS IN INCHES.

Date.	Age.	No. of Cases.	Range.		Average.	Median.	Average deviation.	Probable error.
			From	To				
1881-86	9-10	38	46	58	*52·25	52·59	1·92	1·56
1905-10	9-10	17	48·5	56·0	*51·96	52·06	1·19	1·25
1881-86	10-11	124	46	59	53·2	53·25	1·97	1·8
1905-10	10-11	85	47·5	57·0	52·94	53·31	1·88	1·73
1881-86	11-12	356	46	66	54·38	54·64	1·97	1·75
1905-10	11-12	256	49·25	64·25	54·99	55·06	2·01	2·3
1881-86	12-13	353	48	67	55·94	56·12	2·11	2·4
1905-10	12-13	340	57·0	63·0	56·70	56·88	2·17	2·48
1881-86	13-14	672	48	68	57·77	57·76	2·35	2·30
1905-10	13-14	470	51·0	68·0	58·84	58·9	2·52	2·45
1881-86	14-15	704	48	69	59·82	59·81	2·62	2·52
1905-10	14-15	473	51·0	70·75	61·08	61·4	2·76	2·7
1881-86	15-16	668	48	73	62·16	62·29	3·03	2·76
1905-10	15-16	340	53·0	72·0	63·4	63·83	2·65	2·66
1881-86	16-17	347	55	72·5	63·84	64·21	2·81	2·74
1905-10	16-17	432	53·0	73·5	65·35	66·16	2·48	2·35
1881-86	17-18	115	57	71	65·88	65·66	2·19	2·11
1905-10	17-18	187	59·0	74·5	66·47	66·75	2·13	1·77
1881-86	18-19	32	59	71	*66·98	66·92	1·52	1·42
1905-10	18-19	88	61	72	*66·39	66·66	1·80	1·70
1881-86	19-20	9	61·75	71·5	*67·14	68·00	2·19	2·48
1905-10	19-20	8	61·5	71	*66·2	65·75	3·8	2·8

* Decrease.

Weight in Lbs.

Date.	Age.	No. of Cases.	Range. From	Range. To	Average.	Median.	Average deviation.	Probable error.
1881-86	9-10	38	46	79	61·24	61·00	6·87	7·45
1905-10	9-10	14	52	78	61·93	59·8	4·36	3·0
1881-86	10-11	124	42	98	65·3	65·5	6·86	6·58
1905-10	10-11	54	48	82	65·59	65·66	6·07	6·0
1881-86	11-12	356	40	91	69·28	69·59	6·37	5·94
1905-10	11-12	186	54	117	72·05	71·125	7·85	7·13
1881-86	12-13	356	52	124	74·4	73·88	9·88	8·26
1905-10	12-13	391	59	145	77·3	76·67	8·43	7·21
1881-86	13-14	670	56	140	81·01	80·21	9·66	8·98
1905-10	14-14	469	61	160	85·47	84·2	11·7	10·3
1881-86	14-15	709	54	149	89·99	89·23	12·06	10·94
1905-10	14-15	478	65	186	95·15	95·5	13·3	12·55
1881-86	15-16	671	56	169	101·41	101·89	14·48	13·82
1905-10	15-16	338	70	206·5	105·9	106·3	14·0	13·5
1881-86	16-17	354	72	148	109·65	109·875	14·32	13·02
1905-10	16-17	433	64	186	117·9	119·92	13·39	12·6
1881-86	17-18	118	82	155	119.36	119·33	11·57	11·12
1905-10	17-18	186	84	190	124·84	126·45	13·08	11·65
1881-86	18-19	32	88	160	126·16	128·5	10·97	10·33
1905-10	18-19	89	88	182	127·03	127·25	13·12	11·15
1881-86	19-20	9	107	156·25	133·42	134	14·97	16·53
1905-10	19-20	8	99	202	*132·6	123·5	21·2	15

* Decrease.

CHEST GIRTH IN INCHES.

Date.	Age.	No. of Cases.	Range. From	Range. To	Average.	Median.	Average deviation.	Probable error.
1881-86	9-10	38	22	28	24·30	24·25	1·13	·98
1905-10	9-10	17	22·5	27	24·46	24·22	·86	1·00
1881-86	10-11	124	21	29	24·9	24·79	·99	·72
1905-10	10-11	85	22·25	34·75	*24·68	24·49	1·02	·93
1881-86	11-12	356	22	30	25·21	25·29	·96	·79
1905-10	11-12	256	22·5	32·5	25·38	25·22	1·04	·95
1881-86	12-13	357	22	31	25·92	25·89	1·13	1·03
1905-10	12-13	340	22·75	35	25·93	25·92	1·12	·94
1881-86	13-14	673	23	35	26·72	26·69	1·34	1·23
1905-10	13-14	470	23	36·5	27·05	27·01	1·50	1·27
1881-86	14-15	707	23	36	27·71	27·69	1·44	1·27
1905-10	14-15	478	24	38	28·17	28·15	1·60	1·53
1881-86	15-16	673	24	36	29·26	29·22	1·87	1·5
1905-10	15-16	338	25	39	29·56	29·61	1·63	1·66
1881-86	16-17	354	23	35	30·06	30·18	1·73	1·68
1905-10	16-17	432	25	38·75	30·91	31·15	1·57	1·48
1881-86	17-18	121	26	36	31·3	31·28	1·64	1·54
1905-10	17-18	187	26	38·5	31·85	32·11	1·53	1·40
1881-86	18-19	32	27	35·5	32·21	32·25	1·15	1·17
1905-10	18-19	89	28	39	32·41	32·55	1·68	1·7
1881-86	19-20	9	30·625	36·625	33·81	33·94	1·53	1·53
1905-10	19-20	8	29	38	*32	31·25	2·4	2·25

* Decrease.

UPPER ARM IN INCHES.

Date.	Age.	No. of Cases.	Range.		Average.	Median.	Average deviation.	Probable error.
			From	To				
1881-86	9-10	38	6·375	9·5	7·67	7·594	·59	·65
1905-10	9-10	17	6·75	8·75	*7·515	7·535	·44	·41
1881-86	10-11	124	6·25	9·875	7·81	7·85	·51	·45
1905-10	10-11	85	6·5	9.0	*7·604	7·483	·45	·42
1881-86	11-12	356	6·00	10·0	7·99	8·033	·48	·52
1905-10	11-12	256	6·5	11·125	*7·91	7·87	·52	·44
1881-86	12-13	357	6·5	11·0	8·27	8·25	·52	·47
1905-10	12-13	391	6·5	12·75	*8·11	8·085	·53	·46
1881-86	13-14	674	6·5	11·5	8·63	8·614	·61	·56
1905-10	13-14	470	7·0	12·5	*8·49	8·45	·68	·59
1881-86	14-15	707	7·0	12·25	9·1	9·09	·7	·66
1905-10	14-15	478	7·0	13·25	*8·97	8·97	·71	·64
1881-86	15-16	671	7·5	13·0	9·67	9·71	·89	·75
1905-10	15-16	338	7·25	14·25	*9·48	9·515	·73	·66
1881-86	16-17	354	7·5	13·0	10·19	10·3	·86	·82
1905-10	16-17	431	7·5	13·25	*10·13	10·18	·77	·70
1881-86	17-18	121	8·50	12·75	10·76	10·79	·73	·66
1905-10	17-18	187	8·25	13·25	*10·47	10·585	·77	·72
1881-86	18-19	32	9·125	13·00	11·13	11·25	·74	·70
1905-10	18-19	89	8·5	13·75	*10·5	10·375	·84	·77
1881-86	19-20	9	10·375	13·625	11·97	12·06	·76	1·22
1905-10	19-20	8	9·875	13·75	*11·2	11·3	·95	2·0

* Decrease at all ages.

FOREARM IN INCHES.

Date.	Age.	No. of Cases.	Range.		Average.	Median.	Average deviation.	Probable error.
			From	To				
881-86	9-10	38	6·625	8·625	7·575	7·625	·47	·52
1905-10	9-10	17	6·875	8·625	*7·435	7·40	·32	·37
1881-86	10-11	124	6	9	7·63	7·613	·39	·40
1905-10	10-11	85	6·5	8·625	*7·61	7·47	·35	·40
1881-86	11-12	356	6·5	9·625	7·79	7·8	·39	·45
1905-10	11-12	256	6·75	9·75	7·79	7·813	·37	·34
1881-86	12-13	357	7·75	10·0	7·96	8·053	·46	·40
1905-10	12-13	391	6·75	10·0	7·999	8·045	·40	·43
1881-86	13-14	672	6·5	10·375	8·28	8·319	·48	·41
1905-10	13-14	470	7·0	10·5	8·29	8·22	·51	·47
1881-86	14-15	695	6·5	10·75	8·63	8·65	·51	·49
1905-10	14-15	478	7·0	11·25	8·69	8·605	·56	·52
1881-86	15-16	672	7·0	11·5	9·08	9·104	·59	·58
1905-10	15-16	338	7·5	11·5	9·09	9·115	·55	·53
1881-86	16-17	354	7·5	11·0	9·413	9·517	·57	·50
1905-10	16-17	432	7·75	11·5	9·53	9·605	·57	·59
1881-86	17-18	121	8·25	11·0	9·80	9·94	·51	·50
1905-10	17-18	187	8·125	11·5	*9·79	9·835	·52	·50
1881-86	18-19	32	8·5	11·0	9·84	9·875	·46	·44
1905-10	18-19	89	8·625	12·0	9·9	10·04	·46	·47
1881-86	19-20	9	9·5	11·625	10·54	10·812	·58	·60
1905-10	19-20	8	8·875	12·0	*10·5	9·75	·625	1·4

* Decrease.

COMPARISON OF EMPLOYMENTS OF PARENTS OF NEARLY 1,300 MANCHESTER GRAMMAR SCHOOL BOYS, IN PERIODS 1879-1880-1881 AND 1905-6-7.

Taken consecutively from the Admission Register.

Professional.	1879-81.		1905-7.	
Higher Government Officials, Army, Navy, &c.	9	22·2 %	9	23·5 %
Ministers of Religion	83		42	
Legal Profession	15		25	
Medicine	33		41	
Dentists	9		5	
Accountants	23		18	
Stockbrokers	5		3	
Teaching and allied	29		59	
Land Agents, Architects, Surveyors, Engineers, &c.	80		100	
CLASS TOTAL	286		302	
Commercial.				
Wholesale Manufacturers, &c.	188	68 %	109	66 %
Merchants, Shippers, Yarn Agents, &c.	243		213	
Cashiers, Managers, Secretaries, Travellers, Warehousemen and Inspectors	167		282	
Retail Traders, Shop Assistants, Plumbers, Pawnbrokers, &c.	142		137	
Licensed Victuallers, Hotel Keepers, &c.	44		35	
Printers, Publishers, Journalists, &c.	15		28	
Builders, Contractors, &c.	25		15	
Metal Workers, Ironfounders and Brass Finishers, &c.	24		7	
Artizans and Mechanics	26		27	
CLASS TOTAL	874		853	
Farmers, Agriculturalists, &c.	28		12	
Widows	58		75	
Out of Business	30		35	
Unclassified	9		8	
CLASS TOTAL	125		130	
TOTAL NUMBER OF PARENTS	**1285**		**1285**	

Manchester Memoirs, Vol. lvi. (1912), *No.* 6.

VI. The Synthesis of Hydrocarbons and their Stability at High Temperatures and Pressures.

By J. N. PRING, D.Sc.,

AND

D. M. FAIRLIE, M.Sc.

(*Read November 28th, 1911. Received for publication December 9th, 1911.*)

Carbon and hydrogen, even when in a pure condition, have been found to react directly to give methane at all temperatures up to 1600°, ethylene at 1200° and above, though not in any considerable quantity below 1400—1500°, and acetylene at 1700° and above.*

It was found that no other hydrocarbon can be formed or can exist at any temperature above 1200°.

If the whole of the reaction vessel is at a uniform temperature, the formation of these hydrocarbons will proceed until a certain equilibrium value is in each case reached, when further action ceases, and if, to begin with, any of these hydrocarbons are added in quantities in excess of this value, then decomposition takes place until the same final equilibrium is reached.

The difficulty which was encountered in measuring the equilibrium value of methane is due to the fact that at 1200° and at atmospheric pressure, the reaction between hydrogen and pure carbon is too slow to enable this

* Pring & Hutton, *Trans. Chem. Soc.* (1906), 89, 1591.
Mayer & Altmayer, *Ber.* (1907), 40, 2134.
Bone & Coward, *Trans. Chem. Soc.* (1908), 93, 1975; (1910), 97, 1219.
Pring, *ibid* (1910), 97, 498.
Pring & Fairlie, *ibid* (1911), 99, 1796; (1912), 101, 91.

determination to be made in any reasonable time, and the decomposition of methane at this temperature proceeds still more slowly, though both these reactions can be accelerated by using a catalyst such as platinum or palladium in contact with the carbon.

Again, no substance can be used for the reaction vessel, which can be heated to above 1200°, and remain quite impervious to gases, so it is not practicable to have the whole of the enclosure at a uniform temperature, as was attempted by Berthelot.*

The apparatus by means of which the synthesis of the various hydrocarbons has been observed by the present authors consisted in heating a rod of purified carbon uniformly by means of an electric current.

The rod was mounted in water-cooled electrodes supported in a tubular glass flask, which was filled with pure hydrogen. The carbon itself was thus the only part of the apparatus to be heated. As methane is exothermic, the quantity in equilibrium with carbon and hydrogen is lower the higher the temperature, so that the amount of this hydrocarbon finally formed will correspond to the equilibrium at the temperature of the heated carbon. By this means then an accurate measure could be obtained of the equilibrium value if there is no disturbance by the presence of any other hydrocarbon.

The equilibrium with the endothermic compounds, acetylene and ethylene, could not be determined in this form of apparatus, as the values diminish at lower temperatures, and decomposition of the gas would take place in passing to the cooler parts of the apparatus.

Using platinum as a catalyst, it was found that 0·55 per cent. of methane was finally given at 1200°. and 0·30 per cent. at 1500°.

* *Ann. Chim. Phys.* (1905) [viii.], 6, 183.

However, it was observed that at this temperature a trace of ethylene was produced (about 1 part in 1,000,000). As is well known, this will react with hydrogen at lower temperatures, giving methane, which in this case would raise the amount of the latter above the equilibrium value at the temperature of the rod. It was found that methane is exceedingly stable at 1200°, and could not be decomposed to the equilibrium value, in absence of a catalyst, even after a period of several days.

Data obtained from the above experiments have shown that the whole of the methane obtained at 1200° could not have arisen from this ethylene, but that a considerable part of this quantity was probably derived in this way, and the value did not represent the true equilibrium.

In the case of methane, which is found according to the equation $C + 2H_2 = CH_4$, the criterion of a true equilibrium is that the following conditions shall be satisfied :

(1) At any particular temperature a constant value is given for the ratio of methane to hydrogen.

(2) This same value for the ratio of these gases results when an excess of methane is taken in the first place and allowed to decompose.

(3) The influence of pressure on the reaction shall influence this equilibrium ratio in accordance with the law of mass action, according to which

$$\frac{p \,.\, CH_4}{p \,.\, (H_2)^2} = K \text{ a constant.}$$

According to this

$$\frac{p \,.\, CH_4}{p \,.\, H_2} = K, p \,.\, H_2$$

or the ratio of methane to hydrogen is directly proportional to the pressure of the latter.

It was found that the reaction between carbon and hydrogen is greatly accelerated by increase of pressure and the time necessary for obtaining equilibrium thereby shortened. The complication produced through the formation of ethylene will therefore be very much lessened. The apparatus employed served, moreover, almost completely as a "hot-cold" tube, so that between the range of temperature from 1100° to 1600° quantities of methane were obtained which satisfied the above three requirements of a true equilibrium.

*Apparatus for reactions at high pressures.**

The reaction vessel consisted of a cylinder of nickel-steel of high tensile strength. This was cooled on the outside with water. An inlet valve for the gas was fitted through the walls in the centre, together with a projecting tube provided with a thick glass conical window for sighting through and taking temperature readings with a Wanner optical pyrometer.

The electrodes, consisting of steel tubes cooled by water circulation, were introduced through the two end plates of the cylinder, and passed through stuffing boxes, where insulation from the furnace walls was effected.

The electrodes terminated in nickel clamps, which enabled a firm attachment to be made to the carbon rod.

The windows could usually be used at 200 atmospheres pressure for a few experiments, but numerous cracks gradually developed, which finally led to complete fracture.

The carbon rods used were about 14 cms. long and 10 mms. diameter. In some cases, the carbon was used in

* cf. *Trans. Chem. Soc.* (1912), **101**, 91.

the form of tubes, about 15 mms. external diameter. A current of 500 amps. at 22 volts. would raise this to 1600°, when the pressure was 150 atmospheres.

Somewhat thinner rods were used for producing higher temperatures and also when graphite was used, on account of its higher conductivity.

Hydrogen compressed in cylinders and of about 99·5 per cent. purity was used for these experiments. When working at lower pressures (below 30 atmospheres), the furnace after evacuating was sometimes first filled with pure methane at 1 atmosphere, in order to approach the equilibrium from a quantity slightly in excess of this value.

Results.

A large number of experiments were conducted at various pressures between 20 and 200 atmospheres, and with carbon in various forms and different degrees of purity.

It was found that the amount of methane obtained was always higher with the amorphous form of carbon than with graphite. As is well known, amorphous carbon is unstable above 1200°, and for this reason gives with methane a "false" or "metastable" equilibrium, which is higher than the true value with graphite.

On account of the great inertness of methane, decomposition into the lower value only takes place very slowly.

It was found that with any particular modification of carbon, a constant value within the limits of experimental error was always obtained for the ratio

$$\frac{p\,.\,CH_4}{p\,.\,(H_2)^2},$$

at any given temperature in the range between 1200° and

1600°. Above this temperature, equilibrium values could not be obtained, on account of the comparatively large quantities of ethylene and acetylene which are formed,

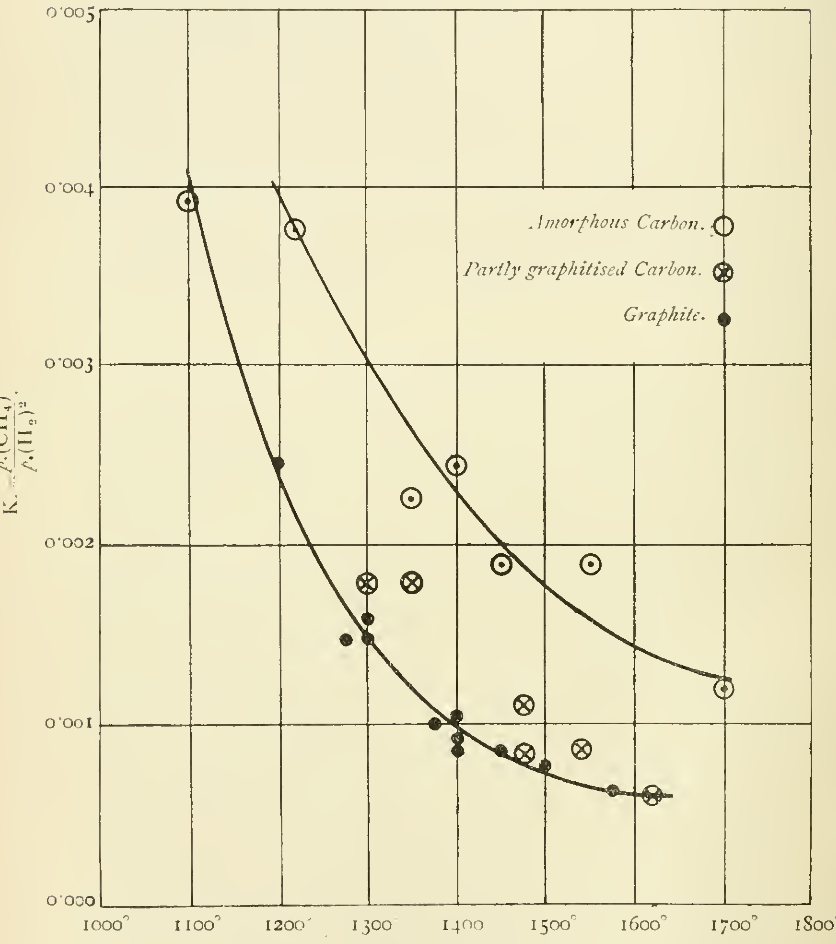


Fig. 1.

and which react rapidly with hydrogen in the cooler parts of the vessel, to give methane. The results are represented in *Fig. 1* in the form of curves, in which the ordinates denote the equilibrium constants or the values

$$\frac{p \cdot CH_4}{p \cdot (H_2)^2},$$

and the abscissae the temperature.

The values obtained with amorphous carbon are not so definite as those with graphite on account of the gradual transformation of the former into graphite, which takes place during the course of the experiment. The values in the diagram represented as amorphous carbon denote samples which were heated for the first time and had undergone a minimum of graphitisation.

Conclusions.

The heat evolved in the transformation of carbon into graphite can be calculated by means of a formula deduced by Van't Hoff. In this

$$Q_{(T)} = RT ln \frac{K_{(1)}}{K_{(2)}}$$

where $Q_{(T)}$ is the heat of reaction at the absolute temperature T. R, the gas constant (1·98), $K_{(1)}$ the equilibrium constant in the methane formula with amorphous carbon, and $K_{(2)}$ that with graphite.

It has been shown by Kirchhoff that the heat of a chemical reaction changes with the temperature in the following manner:

$$Q_{(T)} = Q_{(o)} + T(C(f) - C(e))$$

where $C(f)$ is the mean specific heat of the factors (in this case carbon) and $C(e)$ that of the products of the reaction (in this case graphite).

According to data supplied by Berthelot,* Q has the value 2840 at ordinary temperatures, and the value at high temperatures is seen from these results to be as follows :—

Temp. (absolute).	$Q_{(T)} = RT ln \frac{K_1}{K_2}$
1473°	1290
1573°	2100
1673°	2960
1823°	3740

It follows from these results that the mean specific heat of carbon at these temperatures is higher than that of graphite, and the difference increases rapidly with the temperature.

However, in the values given by Kunz † for carbon, and by Weber ‡ for graphite, the latter has the higher value at all temperatures above 200°. This would lead to the impossible relation that amorphous carbon is at high temperatures more stable than graphite, so that these values, obtained by direct measurement, cannot apply at high temperatures.

In the present work careful analysis of the gases was made as described in earlier work.§ At about 2000°, no marked influence was exerted by pressure on the amounts of ethylene and acetylene produced.

* *Comptes rendus* (1889), **108**, 1144.
† *Ann. Physik*, 1904 [iv.], **14**, 327.
‡ *Ber.*, 1872, **5**, 303.
§ *Trans. Chem. Soc.* (1911), **99**, 1796.

At 1250° the ratio of ethylene to hydrogen was increased by pressure, but the ratio of this hydrocarbon to methane diminished as would be expected from a consideration of the volume changes.

It was found that no saturated hydrocarbon other than methane is produced or is stable under the conditions of temperature and pressure employed.

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Manchester Memoirs, *Vol. lvi.* (1912), *No.* 7.

VII. The Duration of Life of the Common and the Lesser Shrew, with some notes on their Habits.

By LIONEL E. ADAMS, B.A.

(Communicated by Mr. T. A. Coward, F.Z.S.)

(Received November 13th, 1911. Read December 12th, 1911.)

I. THE MOULTS.

Little attention has been given to the moults of our shrews, the best account being that of Barrett-Hamilton in *A History of British Mammals*, Part viii., p. 88, and I may say that this work, which advances our knowledge many stages further than any previous text-book and provides the student with so many points of fresh departure, has suggested the lines of observation detailed in these notes.

Having paid special attention to the subject during the current year (1911) I am able to carry the matter a little further, and I find incidentally that the details of my observations throw additional light on the duration of life of both our shrews, all confirmatory of the hypothesis which I formed some two years ago.*

I will deal with the two moults separately.

A. *The Spring Moult.* The shedding of the winter coat has been observed to extend "from 12th April to 14th June,"† though, of course, it may and probably does

* "A Hypothesis as to the Cause of the Autumnal Epidemic of the Common and the Lesser Shrew." *Manchester Memoirs*, vol. 54, March 31st, 1910.

† Barrett-Hamilton, *op. cit.*

sometimes begin earlier and end later. The shorter summer coat first appears as a patch on the head or neck and thence extends over the back to the tail, the line of demarcation between the two coats being very marked; also loose hairs are very noticeable.

Of course, all those individuals that moult in the spring have the dark coats characteristic of maturity which were acquired during the previous autumn, and the summer coat is of the same dark colour. With the winter coat is shed all, or nearly all the hair on the ears, feet and tail, which parts are never reclothed with a summer pelage.

Now those that have cast their winter coats, and are *ipso facto* adults, do not (so far as my observation goes) participate in the autumn moult of the juveniles.

This is particularly significant, and if my theory that the parent generation dies out every autumn be correct, it is not only quite intelligible but almost indispensable to it; for if the adults are not to live through the winter, why should they perform the useless operation of preparing for it? On the other hand, if the adults do survive the winter, why should they not prepare for it like the juveniles and (?) all other furred creatures?

B. *The Autumn Moult.* Barrett-Hamilton gives the duration of this moult from September 14th to October 7th,* but I have seen individuals incompletely moulted up to November 11th, on which date two specimens were captured without any signs of moult. In order to ascertain the precise duration of the process I kept an unmoulted Common Shrew under observation. He was caught on September 29th. On October 2nd a darker patch appeared on the lower part of the back, and gradually extended till it reached the neck on October 7th.

* *Op. cit.*

On October 8th the upper part of the head and face began to darken, and by October 11th the whole upper surface of the body from nose to tail was of the normal dark colour. Thus, if one may judge from the behaviour of a single captive specimen, the moult is completed in nine or ten days.

In the autumn moult I have only seen a single instance where there was a line of demarcation between the two coats, the dark patch of the winter coat appearing shorter than the surrounding brown ; also loose hairs were not conspicuous, except in the case of a Lesser Shrew, the loose hairs of which called my attention to the fact that moulting was in progress. Indeed, were it not for the dark colour of the winter coat of the Common Shrew contrasting with the light brown of the juvenile pelage the autumn moult might escape notice altogether.

I have examined nearly seventy specimens of the Common Shrew during August, September, October and November, about fifty of which were in the act of moulting, and in every case these were young, brown individuals, born during the current year—the significance of which I have commented upon when dealing with the spring moult.

Of course, the fact that all the summer and autumn adults which have been examined show no trace of reclothing is negative evidence ; but then the whole of the evidence in favour of the theory is of necessity of a negative character, the value of it consisting in the accumulation of facts which all point in one direction, and also in the absence of a single exception to the facts, though exceptions have been most carefully watched for. Altogether more than 500 specimens have been examined.

The evidence for the annual extinction of the parent generation may be summarised as follows :—

1. All individuals examined during and after December are sexually immature.

2. The genitalia of neither males nor females become atrophied as winter approaches. (The contrary is the case with the Moles that have to husband their resources for the next year.)

3. The adults do not provide for the winter by reclothing.

4. The subjoined chart, based on the head-and-body measurements of some 500 specimens, shows that individuals reach their full size in the summer, and then totally disappear.

5. A chart of a similar character, based on the weights of specimens, would show a similar result.

II. NOTES ON HABITS.

During the few days that my captive Common Shrew enjoyed my hospitality he taught me many things, which I hope may be as of much interest to other students of our mammals as they have been to myself.

Found alive in a box-trap on the morning of September 28th I took him home, and at noon installed him in a large glass jar, with half an inch of sand on the bottom, a handful of hay, and a shallow pan of water. Taking it for granted that he was hungry I dropped in beside him a freshly caught dead shrew of his own size. He immediately flew upon it, attacking the belly first. Having torn this open he paid little attention to the intestines, but went for the kidneys, heart, liver and lungs. Within an hour all these parts and a part of the brain had been devoured, and then he darted about excitedly till he stumbled into the water-pan, and began to lap like a dog, with an extremely rapid movement. He then vomited violently, after which he recommenced upon the dead shrew, and presently settled down for a nap. During the afternoon I gave him several bluebottles which he ate greedily. At 5 p.m. I substituted a freshly killed young Bank Vole for the remains of the shrew. This he attacked at once, first eating an ear and then the brain, after which he burrowed for the heart and lungs through the upper part of the thorax. This, I have noticed, is the usual procedure when shrews devour dead mice. Usually, but not invariably, when they have time to finish the banquet, they leave the skin turned inside out with the paws and tail attached to it. This was the condition of the remains of the Bank Vole the next morning and of some others which I gave him, except one the skin of which I found a ragged heap of shreds. On October 4th I left him at night with a large dead Long-tailed Field Mouse weighing 23 grammes. On the morning of October 6th there was nothing left but most of the skin, paws, and leg bones picked clean. During these thirty-six hours he also ate twelve half-grown cockroaches, two small snails (*Helix rufescens*), the following small slugs, six *Agriolimax agrestis*, and five *Arion hortensis*, also three earthworms about three inches long. As the shrew weighed 7 to 8 grammes, he had consumed nearly four times his own weight in thirty-six hours; and it must be remembered that as nothing was left uneaten, the presumption is that he could have eaten more.

On my offering him a large yellow slug (*Limax flavus*) he attacked it without hesitation, but the slime was too much for him, he could get hold neither with teeth nor claws, and after four attacks (from each of which he withdrew to clean the slime off face and paws by rubbing them in the dry sand) he gave it up and went to hunt for something else.

I append a list of insects, etc., offered to him, and his reception of them :—

Flies. Bluebottles, Greenbottles, House Flies, Hover Flies and Drone Flies (*Eristalis tenax*) were all greedily devoured.

Spiders. A very large *Epeira diadema*, a "hay" spider and others devoured at once.

Cockroaches. Devoured at once.

Woodlice. Devoured at once. In fact, I never found the limit of his capacity in respect to all the above ; the supply always gave out before the demand.

A large *Devil's Coach Horse* (*Ocypus olens*) was seized at once, and, in spite of its violent struggles and attempts to bite, was entirely consumed except the mandibles which were bitten off and cast on the ground.

Millipedes were received with only moderate enthusiasm, an *Iulus* being absolutely ignored, while centipedes were eaten when nothing else remained.

Honey Bees. One was eaten after some hesitation ; another was unmolested.

Wasp. This was the only living thing absolutely rejected.

Worms of all sorts were eaten greedily.

Mollusks. Besides those previously mentioned, small snails (*Hyalinia cellaria* and *Hy. alliaria*) were refused at first, but afterwards eaten. A small example of the keeled slug, *Milax Sowerbyi*, was refused at first but afterwards eaten.

After spending half an hour in eating, or rather ferocious gorging, the captive would leave off suddenly, retire to a particular spot amongst the hay and compose himself for a nap. He never attempted to make a nest, but merely snuggled in the hay as it lay on the floor of his den, leaving himself well exposed to view. He would sleep crouched on his belly, tucking his snout straight down through his forelegs under his chest. His slumbers seemed terribly disturbed, and his breathing would become increasingly rapid and spasmodic until the discomfort woke him, when he would again compose himself, and the whole action would be repeated. When he finally roused himself in about half an hour, he would start off frantically in search of more food. Thus alternately eating and sleeping he passed the days and nights.

I never saw him quiet when awake for an instant.

When surrounded with a plethora of worms he would bite them and bury them.

He deposited his copious droppings in the part of his domain most remote from his sleeping-place.

When excited by the pursuit of disabled insects or other things that moved he would give forth a small shrill whistle.

Being specially curious as to whether shrews excavate burrows I filled up his jar with four inches of soil tightly pressed down. He immediately began to burrow scratching out the soil behind him with his forelegs. He was out of sight in 12 seconds, and presently reappeared in a different spot. He seemed to enjoy burrowing; perhaps it cleaned his paws and fur. He would keep one or two burrows open at both ends, and spent much time rushing through them. I renewed the earth daily, and no sooner was this done than he commenced to burrow in it; and it was evident from the purposeful manner in which he burrowed that he was engaged in a habitual action. He never slept in the burrows but always in the hay on the surface, though the custom of the species in this particular during winter cold cannot be judged by the conduct of a well-sheltered captive.

When I gave him his liberty, turning him loose in the garden, he straightway made a long burrow under the surface of a border which I could trace by the upheaval of the earth.

The most interesting peculiarity, however, was the extreme short-sightedness, if not actual blindness, of this little creature. If I put my hand or a stick into the jar, causing a slight disturbance, he would at once become aware of it, and would come and sniff about a finger or stick if either happened to disturb the hay. A wriggling worm, a buzzing fly, or even a creeping spider or wood-louse would soon be located and preyed upon; but a dead bluebottle or motionless worm dangled before him would elicit no response till within an inch of his face, when he would begin to hunt about as if he smelt something, and only when the object came within three-quarters of an inch from his nose would he dart upon it and carry it off. It often happened that in his hurry he would drop the prey, and then he would have to hunt for it afresh, though, of course, it was close to him. In this respect he reminded me very strongly of the procedure of the Mole. His minute beady eyes, like those of bats, *seemed* to be watching me and looking about, but continual tests convinced me that the little creature was practically blind. If the habits of the Common Shrew were specially nocturnal it might be supposed to see better in the dark, but this is certainly not the case; I trap them freely in the daytime, and my captive did not make any difference in his routine night or day.

I never saw him wash his face with his forepaws as small rodents do, but he would often scratch his fur with exceedingly rapid movements of his feet.

His conspicuous characteristic was the spasmodic nervous activity and restlessness of all his actions, in which he reminded me strongly of the Mole, as he did also by his inappeasable appetite (in which, however, he out-moled the Mole); in his manner of lapping water; by the habit of thrusting his flexible trunklike snout enquiringly upwards; his powers of burrowing; his perfect indifference to being stroked or tickled, and lastly by his apparent blindness or extreme short-sightedness.

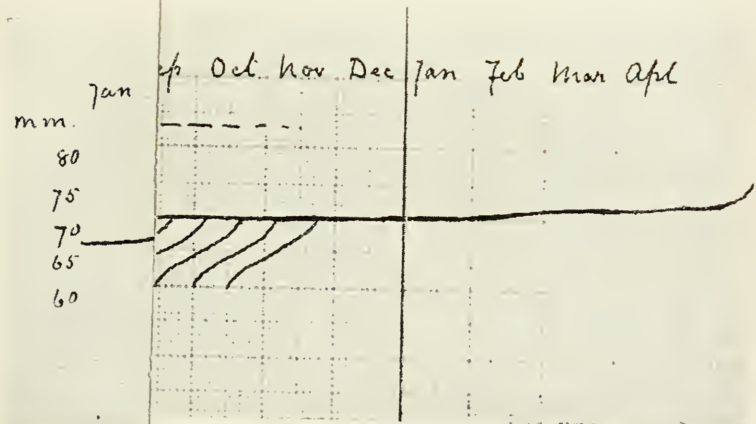
I may mention here that during the heat and drought of this summer the coats of the Common Shrews have been much lighter in colour than usual, white ears also being very common. Formerly white ears were found in, perhaps, 2 per cent. of the specimens handled; this year they occurred in something like 25 per cent.

EXPLANATION OF THE CHART.

The lines indicate the growth of average-sized Common Shrews from the time they leave the nest, the numbers being the measurements of the head-and-body in millimeters.

Quitting the nest from early in June to late October with head-and-body measurement of 60 mm. they quickly reach 70 mm., at which size they remain right through the winter, with an increase of, perhaps, 1 or 2 mm., and suddenly start growing again in May, attaining their maximum in June and July; in autumn they diminish in numbers and disappear. The almost stationary state during the winter is very noteworthy, as is the sudden growth when the breeding season approaches.

Of course these lines on the chart are ideal and only show a rough average; now and then the sizes of the young and old will overlap but not often. It is always perfectly easy to determine to which generation an individual belongs—colour, state of moult and development of genitals all being sure indications.


Jan
ep Oct Nov Dec Jan Feb Mar Apl
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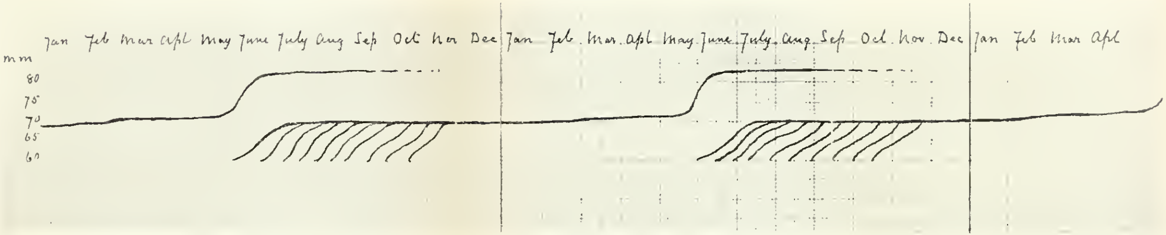
Jan Feb Mar Apl May June July Aug Sep Oct Nov Dec Jan Feb Mar Apl May June July Aug Sep Oct Nov Dec Jan Feb Mar Apl
mm
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VIII. A Note on the Little Owl, *Carine noctua* (Scop.), and its Food.

By T. A. Coward, F.Z.S.

(*Read December 12th, 1911. Received for publication December 13th, 1911.*)

Two problems in connection with the Little Owl have faced British ornithologists for many years; neither is really solved. What is the position of the bird in Britain, and is it worthy of the protection it has hitherto received?

Systematists differ about the correct generic name of the Little Owl. It is usually called *Athene*, but there are other reasons beside priority why *Carine* should be adopted. Seebohm called it *Noctua noctua*, considering that Gerini's genus should be accepted. Amongst the earlier ornithologists the species was frequently confused with the Pygmy Owl, *Strix passerina* of Linnæus.

The range of the Little Owl extends southwards from about 56°N., throughout Europe; and in Africa the northern bird is replaced by a paler and more sandy-coloured species, the Southern Little Owl, *Carine glaux*. At the present time it is a well-established and fairly common breeding species in certain parts of England, where, without doubt, its presence is entirely due to artificial introduction. So far as I am aware, all the introduced birds were brought from the Continent of Europe. The statement that some of them came from Egypt has been contradicted. A valuable paper on "The Spread of the Little Owl from the Chief Centres of its Introduction," by

January 31st, 1912.

H. F. Witherby and N. F. Ticehurst, appeared in Volume I. of "British Birds."[1]

Some authorities maintain that the Little Owl must only be considered as a successful colonist; others, that it is a rare wanderer to the British Islands, or even an occasional immigrant. Most of these latter opinions are founded upon the recorded instances of its occurrence prior to the date of its first known introduction—1843. A critical examination of the earlier records does not strengthen belief in their accuracy. In 1842 Charles Waterton brought some Little Owls from Rome and liberated the survivors, five in number, in the following year in his park at Walton. It is not proved that these birds actually established a colony, but one or two may have nested and others may have wandered. At any rate, in the same year, 1843, there are two records of the bird, one captured alive at Derby and the other seen dead by William Borrer in the Brighton Market. Wolley thought that the Derby bird was a wanderer from Walton.[2] Borrer investigated the Brighton case, and was satisfied that the bird had been shot at Fletching, and had not been imported from the Continent.[3] But that does not prove that it had flown across the Channel; it, too, might be a wanderer from Yorkshire. A bird turned loose in a strange place, even though it had no natural migratory instinct, might wander for any distance.

During the next thirty years we have no actual knowledge of the release of any Little Owls, but Newton and others suggest, not without reason, that the experiment may have been tried either after or before Waterton's

[1] "British Birds" (Jnl.), i., 1907-8, pp. 335-342.

[2] "Zoologist," 1844, p. 645; 1848, p. 2141. Whitlock, F. B., "Birds of Derbyshire," London, 1893, p. 123.

[3] "Birds of Sussex," London, 1891, p. 33.

time by men who kept the matter secret in order to give the colonists a chance. In 1874 Mr. Meade-Waldo began to establish colonies in Kent, and several years later in Hampshire. He naturally waited until the birds were established before he gave the matter publicity, and it is significant that though the later Hampshire experiments are referred to by many writers, it is only recently that the fact of the earlier Kentish colonisation has been made known. Lord Kimberley and Mr. St. Quintin followed Waterton's example in Yorkshire. Lord Lilford turned many birds loose in Northamptonshire, and the Hon. Walter Rothschild released others in Hertfordshire.

One or two of these experiments are said to have been failures because no nests were immediately found in the neighbourhood, but that does not prove anything, for the owls may have nested elsewhere.

An early reference to the bird as British is in Montagu's "Ornithological Dictionary,"[4] under "Owl-Little, *Strix passerina*," which is more correctly the name of the Pygmy Owl.

"We are assured by Mr. Comyns, that a neighbour shot at one of this species in the north of Devon, in the autumn of 1808."

This lucid note is accepted as evidence that the bird is an occasional visitor. Geo. Edwards[5] figures one which was caught alive in a chimney near the Tower of London in 1758, and refers to another in a similar situation in Lambeth. The particulars given, even supposing that the second bird was really a Little Owl, suggest escaped birds.

Pennant, in his "British Zoology," 1812,[6] as well as

[4] Montagu, G., "Ornithological Dictionary," Exeter, 1813. Supplement.

[5] Edwards, G., "Gleanings of Natural History," London, 1758-1764, i., 228.

[6] Pennant. T., "British Zoology," London, 1812, i., 270.

in earlier editions, vaguely mentions that "it is sometimes found in Yorkshire, Flintshire, and also near London." As the Flintshire specimen was apparently Tengmalm's Owl,[7] and as no further information is supplied about the identity of the Yorkshire example, we must dismiss this as unproved, though, unfortunately, the remark is the origin of the inclusion of the bird, as having been taken in Yorkshire and Flintshire, in many lists, including the fourth edition of Yarrell's "British Birds."

In 1811, according to Graves,[8] two occurred at Middleshaw, Westmoreland, on the authority of John Gough, who, though an excellent naturalist, was blind. Gough wrote to Graves that "a pair took up their abode in a barn, in that village, in the spring of 1811, one of which died by some accident; another pair bred in a chimney, in the same neighbourhood, a year or two before." Macpherson doubts the correct identification from description, and adds that even if the blind man had not been misled the birds had probably been liberated by someone in the neighbourhood.[9]

In a little known work, Hunt's "British Ornithology," published in 1815, which I have not seen, a pair are said to have nested near Norwich, and Stevenson[10] mentions one which was killed at Blofield, on the authority of Lombe's notes. The Pagets, in their "Sketch of the Natural History of Great Yarmouth" (1834), state that two were taken in that neighbourhood, but give no particulars. These and many others which are referred

7 Forrest, H. E., "The Vertebrate Fauna of North Wales," London, 1907, p. 213.

8 Graves, G., "British Ornithology," London, 1811-1821, i. (checked from 2nd edition, 1821).

9 Macpherson, H. A., "A Vertebrate Fauna of Lakeland," Edinburgh, 1892, xxiii.

10 Stevenson, T., "Birds of Norfolk," London, 1886, i., 59.

to in local lists or county avifaunas may be errors in identification.

The bird is included for Lancashire by Mitchell, on the strength of one *seen* at Ormskirk "a few years ago" by Thomas Williams, who was "certain of its identity."[11] Many of the records in the "Naturalist's Scrap Book" are unconvincing, and I am surprised that Saunders, when editing the second edition, did not display his usual caution, but apparently accepted this note. He may have satisfied himself that it was correct, but even if it was, what is there to prove whence the bird came?

Taking into consideration the sedentary habits of the species, I am of opinion that there is no *proved* case of regular migration. There are several fairly recent instances of the bird having been met with on the eastern and southern shores, or even taken off-shore on ships, but why should not a bird wander coastwise or be drifted out to sea? Borrer obtained two in Sussex in 1877, and learnt that they had been released intentionally shortly before by a man who had found difficulty in feeding his captives. There is, of course, a possibility of unintentional wandering, due perhaps to wind-drift, from the Continent to England.

The Little Owl, however, deserves a place in our avifauna as a well-established and successful colonist; it must be placed in the same category as the pheasant, which no one now refuses to acknowledge as a British bird.

It is too late to discuss the wisdom of the introduction—the deed is done; the bird is here. But it is well to examine carefully and without prejudice the charge which is now brought against it—that it is destructive to game. Owls,

[11] "Birds of Lancashire," 2nd edition, 1892, p. 120, ex. "Naturalist's Scrap Book," 1863, p. 5.

as a whole, are very rightly claimed as farmers' friends—birds of economic value which do little damage in the game preserves. I have no intention of discussing the ethics of game preservation. I neither attack the attitude of the preserver, who contends that certain creatures are inimical to his interests, nor defend the "shut-eye" policy of the extremist who refuses to listen to any complaint against a bird. We may take it as proved that, with a few exceptions, owls do not kill game, the reason being lack of opportunity. The majority of our owls feed by night, beginning their rounds after dusk. They dare not attack so powerful a bird as an adult pheasant, partridge, or grouse; and at the time that they are normally hunting all well-conducted young game-birds are safe beneath the maternal wing. The Short-eared Owl is more diurnal in its habits, but it is rare as a breeding species in Britain; the Little Owl, also, hunts both by day and night. When, as occasionally happens, a Barn or Tawny Owl is forced by the needs of its family to hunt in the daytime, it will snatch up any small game-bird as readily as any other creature which is edible. The Little Owl finds the foolish pheasant chick easy to capture and tender for its young. Can we blame it if it sins?

Evidence about the food of owls is frequently deduced from the examination and analysis of the contents of cast-up or regurgitated pellets or "plugs." These pellets consist of the indigested portions of the food, sorted out in the crop; in the owls, bone, hard portions of insects, hair and feather. In order, however, to treat the owl fairly we must examine these pellets at all seasons, and also take into consideration the fact that certain soft foods may be passed practically entire into the stomach. If we find no remains of immature game-birds in pellets thrown up at seasons when no such food could be obtained our evidence is unsatisfactory; and considering how the hard bones of mature birds and mammals are broken into fragments, it is possible that softer bones might be digested. I do not intend to argue, from the few pellets which I have personally examined or that I know have been examined by others, that the Little Owl is or is not a useful bird; I merely offer the information derived from these examinations as a contribution to our knowledge of the habits of the bird, and to add a few words on the weakness of arguments based on insufficient data.

Mr. L. E. Adams found evidence that the following animals had been preyed upon in a small series of pellets from Northamptonshire: Field vole, 8; shrew, 7; wood mouse, 2; rat, 1; rabbit, 1; beetle, 1.[12] Mr. Jourdain also quotes an analysis of pellets examined by Von Schweppenburg: Voles, 81·8 %; mice, 8·8 %; birds, 3·2 %; bank-vole, 2·9 %; shrews, 1·8 %; rats, ·3 %; bats, ·3 %.[12]

Unless the examiner is an expert anatomist, and unless he is certain that he has secured all the pellets which were thrown up in a given time, the analysis is not reliable. From observations on a captive Barn Owl, I discovered that the whole of the rejectamenta from a single meal was not thrown up in one pellet, and this is supported by the fact that we frequently find odd jaw-bones of mammals in a pellet. I can only pretend to recognise portions of the crania of mammals and birds, and occasionally other bones, such as a portion of a sternum, a pelvis, or foot. Elytra, legs, or mandibles of insects may serve for identification, but there is always a large quantity of fragmentary remains which may represent more individuals than we can actually be sure about. It is, however, usually possible not only to recognise certain

[12] F. C. R. Jourdain in "The British Bird Book," ii., p. 391. London, 1911.

species, but to form a good idea in what proportion these were eaten by the individual bird. The proportions of the species probably depend more upon the character of the ground over which the particular owl feeds than upon its individual taste.

The few British pellets I have examined, which were all obtained at Stamford, contained remains of house mouse and wood mouse, the former in largest quantities, bank vole, field vole, the leg bones and a few other fragments of a song thrush, a few bones of a frog, fragments of many beetles, a wood louse, and an earwig. Mr. G. A. Dunlop, of Warrington, kindly examined the beetle remains, and found the following species represented: *Pterostichus madidus*, *P. vulgaris*, *Nebria brevicollis*, *Loricera pilicornis* and *Geotrupes stercorarius*.

The main composition of these pellets was mammalian hair, felted in the same way in which we find it in the pellets of the Barn Owl and Heron, but in one or two there was a considerable amount of inorganic matter, a blue-grey clay or earth, which I took to be the oolitic sand of Northamptonshire. One or two pellets were almost entirely composed of clay and remains of beetles.

Some years ago I received a number of pellets of the Southern Little Owl, *Carine glaux*, from Luxor, Upper Egypt. Most of these showed the same inorganic matter in their composition, but in some it was desert sand which had blown over and clung to the outside of the pellets. In other pellets, however, I found considerable quantities of sand mixed with and felted into the hair in the interior of the pellet. It is fair to suggest that the owl, when playing with its quarry, might have dragged the half-devoured portions through the sand and thus accumulated a quantity of inedible inorganic matter, but I think that there is possibly another explanation.

Mr. Meade-Waldo informed Saunders that the Little Owl frequents lawns in the evening in search of earthworms, and others have noticed that the bird will eat worms. It would be practically impossible for the owl to devour a worm without taking into its stomach some of the ingested leaf-mould and soil which was passing through the worm's alimentary canal. This must be got rid of by the owl, and what more natural than that it should be regurgitated with other rejectamenta? The sand was actually inside the skulls of birds and small mammals within the pellets, mingled with mammalian hair.

These Egyptian Owls, judging by the pellets I examined, seem to be less insectivorous than ours. Mr. Oldfield Thomas kindly looked over a few of the bones, and recognised the teeth of the musk shrew, *Crocidura religiosa*, of *Arvicanthis variegatus*, and the Egyptian form of the house mouse, *Mus musculus orientalis*. There were also present several skulls of a passerine bird, almost certainly the house sparrow, and fragments of the skulls of an insectivorous soft-billed bird. The ubiquitous *Passer domesticus* is found amongst the tombs of Luxor.

It was interesting to note the reddish, sandy, or isabelline colour of the mammalian hair in these Nile-side pellets.

Insect remains were comparatively infrequent in the pellets, but in a number were the mandibles and other appendages of the false scorpion, *Galeodes arabs*, C. L. Koch. I am indebted to Mr. A. S. Hirst for the identification of the species. The house mice were in the greatest number, but the shrew remains were numerous. This suggests another possible explanation of the presence of the sand, which, however, is practically the same as the one previously mentioned. The shrews may have eaten the worms and the sand may have been taken by the owl in the stomachs of the shrews. Major Barrett-Hamilton quotes Mr. A. H. Cocks when describing the habits of a captive water shrew, whose diet consisted largely of worms.[13] "Of these (worms) I reckon that she eats quite one-and-a-half her own bulk daily, and fully twice her own weight. The amount which passes from her, consisting chiefly of the earth contained in the worms, is on a correspondingly surprising scale."

I have said that it is unfair to draw conclusions as to the economic value of a species from slender data. I will go further. It is unwise to draw dividing lines between useful and harmful creatures: the animals and plants work together, and their life histories are inextricably interwoven. Who are we to pass judgment upon them?

In his most useful paper on "The Food of Some British Birds,"[14] Prof. R. Newstead divides his insects into three groups—injurious, beneficial, and indifferent. Very roughly the first group is composed of carnivorous, the second of phytophagous, and the third of coprophagous insects. From the insects found in the crops, stomachs, and pellets of certain birds, and also from observations on their habits, he estimates the economic value of these birds to mankind. To a certain extent this is perfectly justifiable, but before we acclaim or condemn we must remember one or two facts. The bird does not wait to ask if the insect is injurious or beneficial, nor does the beneficial carnivorous insect trouble about the moral character of its prey. The phytophagous insect may feed

[13] G. E. H. Barrett-Hamilton, "A History of British Mammals," pt. ix., p. 146. London, 1911. In progress.

[14] "Supplement to the Journal of the Board of Agriculture," xv., No. 9. 1908.

entirely upon troublesome weeds, and surely no one can say that we should be indifferent to the labours of the scavengers! The coprophagous beetle not only removes objectionable and dangerous substances, but buries them beneath the earth, where it gorges itself on the "filth," and, passing it through its own alimentary canal, converts it into valuable manure. Let any who doubt this read the veteran Fabre's "Life and Love of the Insect."

The evidence of the few insects found in the pellets of the Stamford Little Owls would, according to the arbitrary classification, be against the bird. It had eaten four beneficial, one harmful, and one indifferent species. But some of the carnivorous beetles are vegetable feeders also; the indifferent *Geotrupes* must be classed as a most useful ally, and the earwig, though destructive in a garden, does little real damage to food vegetables.

Nor can we safely judge by the vertebrate remains. Shrews, which, as they are insectivorous, are usually classed as beneficial, had been eaten by both the Egyptian and European birds, and the troublesome sparrow had been devoured by apparently the same bird which had eaten a useful insectivorous species. The humanitarian would contend, no doubt, that the Egyptian birds had eaten scorpions, and therefore must be useful, but the false scorpions are not dangerous like their tailed relatives; indeed, they are insectivorous like their other relations, the spiders.

Manchester Memoirs, Vol. lvi. (1912), *No.* 9.

IX. On the modes of rupture of an open hemispherical concrete shell under axial pressure.

By J. R. Gwyther, M.A.

(*Communicated by Mr. R. F. Gwyther, M.A.*)

(*Received and read 23rd January, 1912.*)

This paper is written to describe a few experiments undertaken tentatively in the hopes of obtaining some definite description of the circumstances and mode of rupture as the load is increased, and it is the author's intention to continue the investigation. The specimens experimented on were made of concrete in the proportion of 1 : $1\frac{1}{2}$: 2 of cement, sand and stone, the aggregate being $\frac{1}{4}$-inch granite chippings, and were carefully prepared in wood moulds. After remaining in the moulds for seven days, they were removed and allowed to set under water for a month, and were finally tested four days after being removed from the water. The specimens were then subjected in the ordinary way to compression in a horizontal testing machine with the results to be described. It would perhaps have been preferable to have used a vertical machine for the purpose, since when the load was not removed sufficiently quickly on causing rupture, the specimens were injured by the falling parts.

The author wishes to express his acknowledgments to Mr. J. H. Reynolds, the Principal of the Manchester Municipal School of Technology, to Mr. Popplewell, and to Mr. A. Herring-Shaw for permission to use the laboratories and apparatus.

Six specimens were made and tested, of three sizes with two specimens of each, and at a later period three more specimens were tested. One specimen of each size was reinforced at the base (1a, 2a, 3a in the Table, p. 7). The other specimens of each size were not reinforced (marked 1, 2, and 3 in the Table, p. 7).

The several specimens and the results of the tests are described below, but it appears best to state first the general modes of rupture as the load increases.

First. At some load a longitudinal crack develops which extends gradually in the meridian plane. There are several such cracks fairly regularly distributed, but no doubt decided in position at first by some accidental weakness. When once started they doubtless affect the condition of the specimen.

In the specimens not reinforced at the base, the cracks started at the base; in those which were reinforced at the base they commenced at the top.

Secondly. When the load was increased, and (except in the case of the two smaller specimens) before the longitudinal cracks had extended through the material, rupture took place quite suddenly by a fracture roughly along a parallel of latitude. This fracture was approximately conical and nearly normal to the spherical surfaces, although in all cases the vertex of the cone appeared to be in the axis slightly below the centre of the sphere.

It must be understood that the fracture was irregular, and that the description is of its general character.

Description of the specimens and their rupture.

The specimens were all of the same description of concrete, and the difference between the radii of the bounding spheres was in each case one inch, so that if d is the diameter of the internal sphere in inches, the area of any section parallel to the base is $\pi(d+1)$ square inches. The vertical breaking stress is found in pounds per square inch by dividing the breaking load by the area of the section.

The top was plane and parallel to the base.

The specimens 1. and 1a. had the dimensions:—

internal diameter, 12·5 inches,
external diameter, 14·5 inches,
height, 5·75 inches,

and 1a. was reinforced at the base with two rings of wire one-sixteenth inch diameter, a quarter of an inch from the bottom.

1. The longitudinal cracks first appeared under a load of 3·35 tons, and spread up the dome as the load increased, reaching about three-quarters or four-fifths the height when the specimen broke latitudinally under the load of 4·42 tons, or a vertical breaking stress of 233·6 lbs. per sq. inch. Care was taken in removing the specimen from the machine, the lower portion coming away in pieces, while the top remained intact.

1a. The longitudinal cracks first appeared under the load of 4·01 tons, and in this case started from the top, spreading gradually downwards. When the cracks had reached about two inches from the base the specimen broke latitudinally, as in the previous case, under the load of 11·11 tons, or a vertical breaking stress of 586·7 lbs. per sq. inch. Part of the top collapsed, but the bottom remained whole.

Specimens 2. and 2a. had the following dimensions :—

internal diameter, 9 inches.
external diameter, 11 inches.
height, 4·25 inches,

and 2a. was reinforced at the base with two rings of one-sixteenth inch diameter wire.

2. Longitudinal cracks first appeared under a load of 2·6 tons, commencing at the base and spreading upwards, but did not reach the top, being higher on the outside than the inside. The latitudinal rupture took place under the load of 4·6 tons and was irregular, the vertical breaking stress in this case being 328 lbs. per sq. inch. On removing the specimen from the machine the lower portion was found to be in sections, but the top held together.

2a. Longitudinal cracks appeared under a load of 7·25 tons and spread from the top downwards as the load increased. At the load of 10·68 tons the specimen broke latitudinally, the top collapsed, and, falling inwards, broke a part of the base to the level of the reinforcement, the longitudinal cracks not having reached the reinforcement. The breaking stress was in this case 761·4 lbs. per sq. inch. The load was not removed sufficiently quickly, and the injury to the specimen was partly due to testing it in a horizontal machine. The latitudinal crack was irregular but roughly normal to the surface.

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The dimensions of specimens 3. and 3a. were as follows :—

internal diameter, 6 inches,
external diameter, 8 inches,
height, 2·75 inches,

and 3a. was reinforced at the base.

3. In this case the longitudinal cracks appeared under a load of 3·36 tons. They spread upwards and the specimen parted in sections, three to four inches in width at the base, under a load of 4·72 tons or a vertical breaking stress of 481 lbs. per sq. inch. There was no latitudinal crack.

3a. This specimen was reinforced at the base, and longitudinal cracks first appeared under a load of 5·2 tons, and spread from the top downwards as the load increased. At the load of 12·32 tons, giving a breaking stress of 1254·9 lbs. per sq. inch, the specimen collapsed, shearing off at the base, just above the level of the reinforcement, leaving only the inner half of the thickness of the base with the reinforcement standing. There was no latitudinal crack.

Having experimented on domes of three different sizes, first without reinforcement, then with reinforcement at the base to prevent spreading, I next decided to test further specimens of the same size as before, but reinforced with wire rings both at the top and bottom to prevent any spreading movement starting either at the top or bottom with the results and the modes of rupture described below.

General mode of rupture of specimens reinforced top and bottom.

Firstly. At some load cracks developed in meridian planes round the middle of the dome, spreading up and down as the load increased.

Secondly. When the load was increased and before the cracks had extended to the top or bottom, rupture took place quite suddenly by an irregular fracture roughly along a parallel of latitude, and, as in the case of the former experiments, was approximately conical, and nearly normal to the spherical surfaces, although in each case the vertex of the cone appeared to be in the axis and slightly below the centre of the sphere. As the rupture took place there was an extension of the meridional cracks.

1b. The longitudinal cracks first appeared under the load of 6·03 tons at intervals averaging roughly two inches round the middle of the dome, and spread gradually up and down. When these cracks had almost reached the top and bottom, the specimen broke latitudinally under the load of 20·35 tons, giving a breaking stress of 1074·8 lbs. per sq. inch, the average height being about three inches. The specimen was removed from the machine in two pieces.

2b. Longitudinal cracks appeared round the middle as in 1b., in this case under the load of 7·12 tons, spreading gradually as the load increased. At the load of 20·63 tons, a breaking stress of 1470·7 lbs. per sq. inch, the specimen broke latitudinally, the longitudinal cracks not having reached the reinforcements at the top or base. Again the latitudinal crack was irregular and was at an approximate mean height of $2\frac{3}{4}$ inches from the bottom.

3b. Longitudinal cracks first appeared in meridian planes under a load of 8·5 tons and spread as in the other cases, but ultimately reached both reinforcements, the whole breaking and falling to pieces under a load of 21·2 tons, having sheared through at the level of the reinforcements. The breaking stress in this case was 2159·4 lbs. per sq. inch. The broken pieces appeared to indicate that the specimen had fractured roughly along a parallel of latitude just as the longitudinal cracks reached the reinforcements, the whole collapsing instantaneously.

Table showing Vertical Breaking Loads in Tons and Breaking Stresses in Pounds per square inch.

PLAIN.

No. of Specimen.	Load.	Stress.
1.	4·42	233·6
2.	4·6	328·0
3.	4·72	481·0

REINFORCED AT BASE.

1a.	11·11	586·7
2a.	10·68	761·4
3a.	12·32	1254·9

REINFORCED BOTH AT BASE AND CROWN.

1b.	20·35	1074·8
2b.	20·63	1470·7
3b.	21·2	2159·4

Summary of the results.

(1) The longitudinal cracks in meridional planes only develop under considerable loads and extend slowly. As concrete is understood not to be able

to resist tension, the conclusion must be that the "ring tension" is comparatively small. The theory of the "Angle of Rupture" does not apply to cases of externally applied load, and it probably is not applicable even to a concrete dome under its own weight.

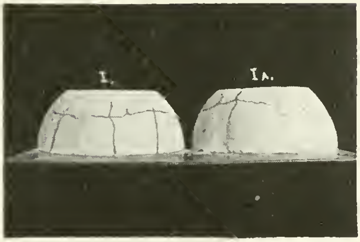
(2) Whatever the size of the example on which the experiments have been carried on, the fracture has occurred under the same conditions (except in the case of the smallest specimens) for practically the same load, and not for the same stress. It may be concluded that the cause of the fracture is not 'shear' under which concrete is supposed to be apt to break, but it breaks in consequence of an excessive 'bending moment,' or otherwise stated, that the resultant stress on some section fails to act within the 'middle third.'

(3) The section in which the fracture takes place appears to be approximately on a cone of which the centre of the sphere is the vertex. The mean height of the fracture is about ·66 of the height of the shell.

(4) The angle of the cone does not vary very greatly with the reinforcement given to the concrete.

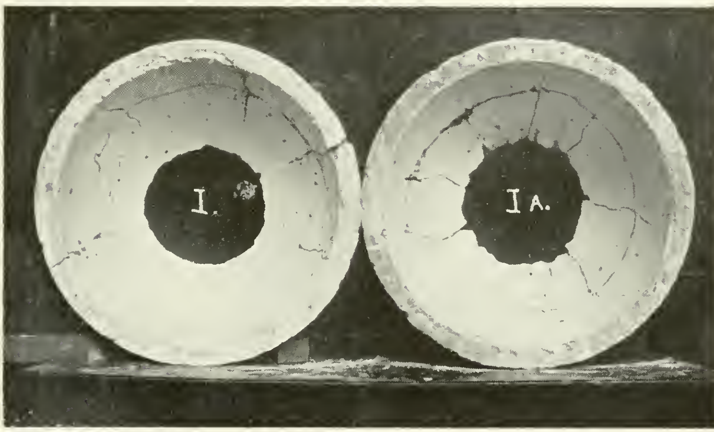
(5) The load which the specimen will bear without rupture is greatly increased by reinforcement at the lower rim, and is again greatly increased by reinforcement at both top and bottom.

It is desirable that a greater number of experiments should be made, as it is probable that a very slight displacement of the reinforcing wires may make a very considerable difference in the load which the specimen can bear without fracture.

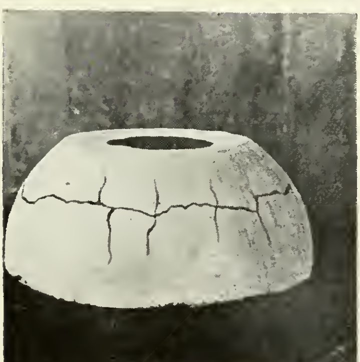


Specimen 1 and 1a. (Elevation.)

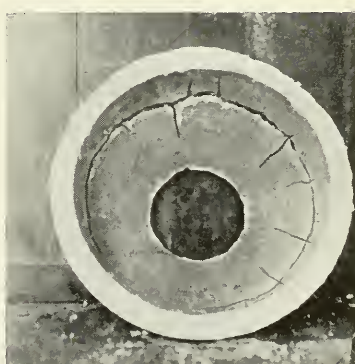
Specimen 3. (Elevation and Section.)



Specimen 1 and 1a. (Interior.)



Specimen 1b. (Elevation.)



Specimen 2b. (Interior.)

X. The formal specification of the elements of stress in cartesian, and in cylindrical and spherical polar coordinates.

By R. F. Gwyther, M.A.

(*Received March 8th, 1912. Read March 19th, 1912.*)

This paper is a prefatory paper, as it is concerned with the collection of material necessary for the application of a novel method to the investigation of stresses in material structures.

The interest no doubt begins with the applications, but no such application accompanies this part of an uncompleted investigation.

The usual method in Elasticity has been to assume from the beginning that Hooke's Law is obeyed, and thus to make the equations of displacement replace the equations of stress, and so become the fundamental subject of investigation, the question of surface-tractions being considered later.

The method I now propose follows a different order of investigation, the equations of stress being solved as the first step. Such solutions are then to be conditioned so as to be able to satisfy the surface-tractions. Lastly, the question whether the solution can be made to satisfy Hooke's Law is to be taken as the final condition.

It is possible that the application of this final condition may indicate to what extent and in what way the failure to follow Hooke's Law may show itself.

May 13th, 1912.

Cartesian Coordinates.

The equations of stress, with the usual notation, are

$$\frac{dP}{dx}+\frac{dU}{dy}+\frac{dT}{dz}=X,$$

$$\frac{dU}{dx}+\frac{dQ}{dy}+\frac{dS}{dz}=Y,$$

$$\frac{dT}{dx}+\frac{dS}{dy}+\frac{dR}{dz}=Z \quad . \quad . \quad . \quad . \quad . \quad . \quad (1),$$

where X, Y, Z are to include 'inertia terms' as well as forces.

I shall assume that we may write

$$X=\frac{d\phi}{dx}+\frac{dN}{dy}-\frac{dM}{dz},$$

$$Y=\frac{d\phi}{dy}+\frac{dL}{dz}-\frac{dN}{dx},$$

$$Z=\frac{d\phi}{dz}+\frac{dM}{dx}-\frac{dL}{dy} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

The equations (1) can, of course, only have solutions which are to some extent indefinite, but the *form* of the solutions may be quite definite, and it is proposed to find these formal solutions or specifications of stress.

We shall, in the first place, find *particular integrals*, and then the *complementary functions*, to use the terminology of ordinary differential equations.

When the values of X, Y and Z are given in any special case, the particular integrals will probably be readily found. But for the purpose of what follows later, it will be well to give a general method of procedure, although that method need not be followed in each special case.

The particular integral solution.

Assume

$$P_0 = \phi_1, \quad S_0 = 0,$$

$$Q_0 = \phi_2, \quad T_0 = 0,$$

$$R_0 = \phi_3, \quad U_0 = 0;$$

and

$$P_1 = 2\frac{dv}{dy} + 2\frac{dw}{dz},$$

$$Q_1 = 2\frac{du}{dx} + 2\frac{dw}{dz},$$

$$R_1 = 2\frac{du}{dx} + 2\frac{dv}{dy},$$

$$S_1 = -\frac{dw}{dy} - \frac{dv}{dz},$$

$$T_1 = -\frac{du}{dz} - \frac{dw}{dx},$$

$$U_1 = -\frac{dv}{dx} - \frac{du}{dy}, \qquad \ldots \ldots \ldots \quad (3).$$

Then we shall require that

$$\frac{d\phi_1}{dx} = \frac{d\phi}{dx}, \quad \frac{d\phi_2}{dy} = \frac{d\phi}{dy}, \quad \frac{d\phi_3}{dz} = \frac{d\phi}{dz};$$

and

$$\frac{dw}{dy} - \frac{dv}{dz} = L, \quad \frac{du}{dz} - \frac{dw}{dx} = M, \quad \frac{dv}{dx} - \frac{du}{dy} = N, \quad . \quad (4),$$

as the conditions for satisfying (1) and (2).

I have retained ϕ_1, ϕ_2, ϕ_3, with their definition in (4), because, although we might replace each of them by ϕ. The single function ϕ is ordinarily introduced, partly for the sake of form and partly because in ordinary dynamical problems it represents a form of "energy," but in the case under consideration these arguments are void, and each of the quantities ϕ_1, ϕ_2, ϕ_3 will have its simplest value. For an illustration, note a heavy body rotating about a vertical axis, in which case the different values of ϕ_1, ϕ_2 and ϕ_3 are too obvious to require description.

If the single function should be retained, it would be necessary to *correct* by terms from the complementary function to which we now proceed.

The Complementary Function Solution.

The right hand side of equations (1) must for this purpose be replaced by zero, and the solution should contain *six* arbitrary functions.

If we replace each of the stresses by the general linear expression of second-differential coefficients of a function, we shall have 6 arbitrary constants in the expression for each stress, and therefore 36 such constants altogether.

Substituting in the stress equations, we should obtain three linear expressions of third-differential coefficients, each of which is to vanish, and we should therefore obtain 30 linear equations of condition between the arbitrary constants, leaving *six* independent and arbitrary constants.

As in the ordinary theory of differential equations, each independent arbitrary constant corresponds to an arbitrary function. This plan therefore leads to the complete solution or specification required.

The labour is made quite slight by the consideration of the stress equations to be solved : for we may conclude; —(*a*) that P will contain no differential coefficient in x, Q none in y, and R none in z;—(*b*) that S will contain no second-differential coefficient in either y or z, T none in either z or x, U none in either x or y.

The solution is

$$
\begin{aligned}
P_2 &= \frac{d^2\Theta_3}{dy^2} - 2\frac{d^2\Psi_1}{dydz} + \frac{d^2\Theta_2}{dz^2}, \\
Q_2 &= \frac{d^2\Theta_3}{dx^2} - 2\frac{d^2\Psi_2}{dxdz} + \frac{d^2\Theta_1}{dz^2}, \\
R_2 &= \frac{d^2\Theta_2}{dx^2} - 2\frac{d^2\Psi_3}{dxdy} + \frac{d^2\Theta_1}{dy^2}, \\
S_2 &= -\frac{d^2\Psi_1}{dx^2} + \frac{d^2\Psi_2}{dxdy} + \frac{d^2\Psi_3}{dxdz} - \frac{d^2\Theta_1}{dydz}, \\
T_2 &= +\frac{d^2\Psi_1}{dxdy} - \frac{d^2\Theta_2}{dxdz} - \frac{d^2\Psi_2}{dy^2} + \frac{d^2\Psi_3}{dydz}, \\
U_2 &= -\frac{d^2\Theta_3}{dxdy} + \frac{d^2\Psi_1}{dxdz} + \frac{d^2\Psi_2}{dydz} - \frac{d^2\Psi_3}{dz^2} \quad . \quad (5).*
\end{aligned}
$$

The complete solution finally is

$P = P_o + P_1 + P_2$, etc.,

$S = S_1 + S_2$, etc., from (3) and (5).

We have now obtained an explicit statement for the elements of stress, applicable to all substances for which these elements are continuous functions of the coordinates. They may be taken to apply to most materials for construction, and to apply fairly well to earth pressures on a retaining wall, and less definitely to the pressures in a corn bin or bunker or in a quicksand, but for different reasons.

Avoiding such special cases, we have to consider (1) cases where Hooke's Law of connection between stress and strain holds good, (2) cases where the elastic limit is exceeded, (3) cases where a viscous flow of the material is set up, and (4) the conditions for rupture.

* In a paper by Sir G. B. Airy, published as a Report by the British Association (1862, page 82), the value of a general solution is minimised. But giving the fullest value to that investigation, the solution there proposed is covered if the Θ-functions alone in (5) are retained, and the Ψ-functions ignored.

It is not proposed to consider all these cases in this paper, but only to set out general lines for investigation, taking the case of Hooke's Law as the general case, but having regard to departures from it.

If Hooke's Law held universally, we should have a second explicit expression for the stresses in terms of the strains, and ultimately in terms of the three components of the displacement.

With two explicit forms for the elements of stress, there are three modes of further investigation open :

(1) To take the Hooke's Law specification as absolute and to substitute in the statical equations.

This has been the practice.

(2) To take the statical specification as absolute and to find the cases which satisfy Hooke's Law.

(3) To combine the two specifications as may be found analytically most convenient in any case.

This last method will doubtless be found convenient in many cases, but it may be accompanied by the drawbacks which are inherent in the combination of two independent methods.

I proceed with the second method with the object of bringing into prominence the analytical connection which is now to be demonstrated between the statical expressions for the stress and the geometrical conditions which are consequent on the fulfilment of Hooke's Law.

The Geometrical conditions affecting elements of strain.

Using the adopted notation for strains, the conditions are well known to be

$$0 = \frac{d^2g}{dy^2} + \frac{d^2f}{dz^2} - \frac{d^2a}{dydz},$$

with two analogous equations;

$$0 = \frac{1}{2}\frac{d}{dx}\left(-\frac{da}{dx} + \frac{db}{dy} + \frac{dc}{dz}\right) - \frac{d^2e}{dydz},$$

with two analogous equations . . . . (6).

On comparison of the right-hand side of these equations with the right-hand side of the equations (5), it is seen that they become identical on the substitution of

$$\Theta_1 \text{ for } e, \quad \Theta_2 \text{ for } f, \quad \Theta_3 \text{ for } g;$$

$$2\Psi_1 \text{ for } a, \quad 2\Psi_2 \text{ for } b, \quad 2\Psi_3 \text{ for } c,$$

This general relation will be made use of at a later period in the paper.

Within the limits to which Hooke's Law applies, the elements of the strain can be replaced by a linear function of the elements of the stress with constant coefficients, and if the coefficients are allowed to be variable the substitution may be made, even though Hooke's Law no longer obtains. I shall, however, here limit myself to the case of a homogeneous isotropic elastic solid, and write

$$qe = (1+\sigma)P - \sigma(P+Q+R),$$

with two analogous relations;

$$qa = 2(1+\sigma)S,$$

with two analogous relations,

where q and σ are constants.

Then for the relations affecting the stresses in such a solid, we shall have

$$0 = (1+\sigma)\left\{\frac{d^2R}{dy^2} + \frac{d^2Q}{dz^2} - 2\frac{d^2S}{dydz}\right\} - \sigma\left(\frac{d^2}{dy^2} + \frac{d^2}{dz^2}\right)\left\{P+Q+R\right\},$$

with two analogous relations,

$$0 = (1+\sigma)\left\{\frac{d}{dx}\left(-\frac{dS}{dx} + \frac{dT}{dy} + \frac{dU}{dz}\right) - \frac{d^2P}{dydz}\right\} + \sigma\frac{d^2}{dydz}\left\{P+Q+R\right\},$$

with two analogous relations . . . . (7).

Taking into consideration the three forms of solution (from (3) and (5)), we obtain as the final relations for a homogeneous isotropic elastic solid,

$$(1+\sigma)\left\{\frac{d^2R_2}{dy^2}+\frac{d^2Q_2}{dz^2}-2\frac{d^2S_2}{dydz}\right\}-\sigma\left(\frac{d^2}{dy^2}+\frac{d^2}{dz^2}\right)\left\{P_2+Q_2+R_2\right\}$$

$$+\frac{1-\sigma}{2}\left(\frac{d^2}{dy^2}+\frac{d^2}{dz^2}\right)\left\{P_1+Q_1+R_1\right\}$$

$$-\frac{d^2}{dy^2}\left\{\sigma(P_o+Q_o)-R_o\right\}-\frac{d^2}{dz^2}\left\{\sigma(P_o+R_o)-Q_o\right\}=0$$

with two analogous equations;

and

$$(1+\sigma)\left\{\frac{d}{dx}\left(-\frac{dS_2}{dx}+\frac{dT_2}{dy}+\frac{dU_2}{dz}\right)-\frac{d^2P_2}{dydz}\right\}+\sigma\frac{d^2}{dydz}\left\{P_2+Q_2+R_2\right\}$$

$$-\frac{1-\sigma}{2}\frac{d^2}{dydz}\left\{P_1+Q_1+R_1\right\}$$

$$+\frac{d}{dydz}\left\{\sigma(Q_o+R_o)-P_o\right\}=0$$

with two analogous equations . . . (8).

In order to make use of these solutions, the surface-traction conditions must be employed, and unless these are readily applicable and tend to simplify the arbitrary functions, it would appear that a different choice of coordinates should here be made. Generally, the cartesian system of coordinates will only suit slab-sided figures.

I now proceed to consider other coordinate systems, but I only propose in each case to deal with the *complementary function* solution, as the *particular integral* solution can be treated in each particular case as I have already shown for cartesian coordinates

Cylindrical polar coordinates.

The stress equations in this case are

$$\frac{1}{r}\frac{d}{dr}(Pr)+\frac{1}{r}\frac{dU}{d\theta}+\frac{dT}{dz}-\frac{Q}{r}=X,$$

$$\frac{1}{r^2}\frac{d}{dr}(Ur^2)+\frac{1}{r}\frac{dQ}{d\theta}+\frac{dS}{dz}\qquad=Y,$$

$$\frac{1}{r}\frac{d}{dr}(Tr)+\frac{1}{r}\frac{dS}{d\theta}+\frac{dR}{dz}\qquad=Z \quad . \quad . \quad . \quad . \quad (9).$$

With the guidance given by having obtained the *complementary function* solution in cartesians, it is not difficult to determine the corresponding solution in this case, namely—

$$P_2=\frac{1}{r^2}\frac{d^2\Theta_3}{d\theta^2}-\frac{2}{r}\frac{d^2\Psi_1}{d\theta dz}+\frac{d^2\Theta_2}{dz^2}+\frac{1}{r}\frac{d\Theta_3}{dr}-\frac{2}{r}\frac{d\Psi_2}{dz},$$

$$Q_2=\frac{d^2\Theta_3}{dr^2}-2\frac{d^2\Psi_2}{drdz}+\frac{d^2\Theta_1}{dz^2},$$

$$R_2=\frac{d^2\Theta_2}{dr^2}-\frac{2}{r}\frac{d^2\Psi_3}{drd\theta}+\frac{1}{r^2}\frac{d^2\Theta_1}{d\theta^2}+\frac{2}{r}\frac{d\Theta_2}{dr}-\frac{1}{r}\frac{d\Theta_1}{dr}-\frac{2}{r^2}\frac{d\Psi_3}{d\theta},$$

$$S_2=-\frac{d^2\Psi_1}{dr^2}+\frac{1}{r}\frac{d^2\Psi_2}{drd\theta}+\frac{d^2\Psi_3}{drdz}-\frac{1}{r}\frac{d^2\Theta_1}{d\theta dz}-\frac{1}{r}\frac{d\Psi_1}{dr}-\frac{1}{r^2}\frac{d\Psi_2}{d\theta}+\frac{2}{r}\frac{d\Psi_3}{dz}+\frac{\Psi_1}{r^2},$$

$$T_2=\frac{1}{r}\frac{d^2\Psi_1}{drd\theta}-\frac{1}{r^2}\frac{d^2\Psi_2}{d\theta^2}+\frac{1}{r}\frac{d^2\Psi_3}{d\theta dz}-\frac{d^2\Theta_2}{drdz}+\frac{1}{r^2}\frac{d\Psi_1}{d\theta}+\frac{1}{r}\frac{d\Theta_1}{dz}-\frac{1}{r}\frac{d\Theta_2}{dz},$$

$$U_2=\frac{d^2\Psi_1}{drdz}+\frac{1}{r}\frac{d^2\Psi_2}{d\theta dz}-\frac{d^2\Psi_3}{dz^2}-\frac{1}{r}\frac{d^2\Theta_3}{drd\theta}+\frac{1}{r^2}\frac{d\Theta_3}{d\theta}-\frac{1}{r}\frac{d\Psi_1}{dz} \quad . \quad . \quad . \quad (10).$$

In accordance with the relation noticed in cartesians between (5) and (6), we may similarly deduce from (10) the relations connecting the elements of the strain.

It seems unnecessary to reproduce either this system of equations, or the system of equations corresponding with (7) or (8).

If the complete circumstances involve symmetry about the cylindrical axis, the whole system is simplified by the independence of all functions of the coordinate θ.

Spherical Polar Coordinates.

In a paper* read before the Society a year ago, I proposed an alteration in the representation of the displacements for such a system of coordinates, the proposed form being

$$u, \quad \sin\theta\, v, \quad \sin\theta\, w.$$

The elements of the strain consequently may be written

$$\{e, \ f, \ g, \quad a, \quad b\sin\theta, \quad c\sin\theta\}.$$

and those of the stress

$$\{P, \ Q, \ R, \quad S, \quad T\sin\theta, \quad U\sin\theta\}.$$

I shall assume that this system is employed, and shall write, as is usual, x in place of $\cos\theta$.

The equations of stress then become

$$\frac{1}{r^2}\frac{d}{dr}(Pr^2) - \frac{1}{r}\frac{d}{dx}\left\{(1-x^2)U\right\} + \frac{1}{r}\frac{dT}{d\phi} - \frac{1}{r}(Q+R) = X,$$

$$\frac{1}{r^3}\frac{d}{dr}(Ur^3) - \frac{1}{r}\left(\frac{dQ}{dx} - \frac{Qx}{1-x^2}\right) + \frac{1}{r(1-x^2)}\frac{dS}{d\phi} - \frac{Rx}{r(1-x^2)} = \frac{Y}{\sin\theta} = Y',$$

$$\frac{1}{r^3}\frac{d}{dr}(Tr^3) - \frac{1}{r(1-x^2)}\frac{d}{dx}\left\{(1-x^2)S\right\} + \frac{1}{r(1-x^2)}\frac{dR}{d\phi} = \frac{Z}{\sin\theta} = Z' \quad (11).$$

The Complementary Function Solution.

The expressions corresponding with those of (5) are long, but this is inevitable in view of the generality of

* *Manchester Memoirs*, vol. iv. (1911), No. 20.

TABLE A

$$P_2 = \frac{1-x^2}{r^2}\frac{d^2\Theta_1}{dx^2} + \frac{2}{r^2}\frac{d^2\Psi_1}{dx\,d\phi} + \frac{1}{r^2(1-x^2)}\frac{d^2\Theta_2}{d\phi^2} + \frac{1}{r}\frac{d}{dr}(\Theta_2 + \Theta_3) + \frac{1}{r^2}\left\{x\frac{d}{dx}(\Theta_2 - 3\Theta_1) + 2(1-x^2)\frac{d\Psi_3}{dx}\right\} - \frac{2}{r^2}\frac{d}{d\phi}\left\{\Psi_2 + \frac{x}{1-x^2}\Psi_1\right\} + \frac{2}{r^2}(\Theta_2 - \Theta_1 - x\Psi_3)$$

$$Q_2 = \frac{d^2\Theta_3}{dr^2} - \frac{2}{r}\frac{d^2\Psi_2}{dr\,d\phi} + \frac{1}{r^2(1-x^2)}\frac{d^2\Theta_1}{d\phi^2} + \frac{1}{r}\frac{d}{dr}(2\Theta_3 - \Theta_1 - 2x\Psi_3) - \frac{x}{r^2}\frac{d\Theta_1}{dx} - \frac{2}{r^2}\frac{d\Psi_2}{d\phi} - \frac{2x}{r^2}\Psi_3,$$

$$R_2 = \frac{d^2\Theta_2}{dr^2} + \frac{2(1-x^2)}{r}\frac{d^2\Psi_3}{dr\,dx} + \frac{1-x^2}{r^2}\frac{d^2\Theta_1}{dx^2} + \frac{1}{r}\frac{d}{dr}(2\Theta_2 - \Theta_1 - 2x\Psi_3) - \frac{1}{r^2}\left\{x\frac{d\Theta_1}{dx} - 2(1-x^2)\frac{d\Psi_3}{dx}\right\} - \frac{2x}{r^2}\Psi_3,$$

$$S_2 = -\frac{d^2\Psi_1}{dr^2} - \frac{1-x^2}{r}\frac{d^2\Psi_3}{dr\,dx} + \frac{1}{r}\frac{d^2\Psi_2}{dr\,d\phi} + \frac{1}{r}\frac{d^2\Theta_1}{dx\,d\phi} - \frac{2}{r}\frac{d\Psi_1}{dr} - \frac{1-x^2}{r^2}\frac{d\Psi_2}{dx} + \frac{1}{r}\frac{d}{d\phi}\left\{\Psi_3 + \frac{x}{1-x^2}\Theta_1\right\},$$

$$T_2 = -\frac{1}{r}\frac{d^2\Psi_1}{dr\,dx} - \frac{1}{r(1-x^2)}\frac{d^2\Theta_2}{dr\,d\phi} - \frac{1-x^2}{r^2}\frac{d^2\Psi_2}{dx^2} - \frac{1}{r^2}\frac{d^2\Psi_3}{dx\,d\phi} + \frac{2x}{r(1-x^2)}\frac{d\Psi_1}{dr} + \frac{4x}{r^2}\frac{d\Psi_2}{dx} + \frac{1}{r^2(1-x^2)}\frac{d\Theta_1}{d\phi},$$

$$U_2 = \frac{1}{r}\frac{d^2\Theta_3}{dr\,dx} + \frac{1}{r(1-x^2)}\frac{d^2\Psi_1}{dr\,d\phi} - \frac{1}{r^2}\frac{d^2\Psi_2}{dx\,d\phi} - \frac{1}{r^2(1-x^2)}\frac{d^2\Psi_3}{d\phi^2} + \frac{x}{r(1-x^2)}\frac{d}{dr}(\Theta_2 - \Theta_3) - \frac{1}{r^2}\frac{d\Theta_1}{dx} + \frac{2x}{r^2(1-x^2)}\frac{d\Psi_2}{d\phi} - \frac{2}{r^2}\Psi_3 \quad \ldots (12)$$

the solution. The simplifications will not appear until a particular application is attempted, when the terms will fall into groups. The terms of the second order in the solution can be written down, and the other terms can be deduced by substitution in the stress equations. The result is as follows (12):

See Table A for equations (12).

These lead at once to the expressions connecting the strains corresponding with (6).

This paper has only dealt with the preparation of an instrument for use on simple examples, but I feel sure that it is well to have these cases treated in full. No doubt, for completion, the case of curvilinear coordinates should have been included, but this offers no considerable difficulty, and may well be deferred till the question of its use in Geostatics arises.

Although the paper contains no illustrative applications, I may perhaps be allowed to state that I have taken some steps to satisfy myself that the method proposed appears to be of practicable application to the theory of the cylindrical test-piece in Mechanical Engineering and to the theory of arches and domes in Civil Engineering.

Although I shall not consider any precise problem, each of which will require its special method of final treatment for surface-tractions, etc., I wish to show some grounds for the belief which I have expressed that the method of this paper lends itself to the treatment of particular cases.

For this purpose I have selected the case of a body symmetrical about an axis, and subject to surface-tractions only, also symmetrical about that axis. That is, I select the case of cylindrical polars, in which θ does not enter.

The expressions for the elements of stress (10) then become

$$P = \frac{d^2\Theta_2}{dz^2} + \frac{1}{r}\left(\frac{d\Theta_3}{dr} - 2\frac{d\Psi_2}{dz}\right),$$

$$r\frac{dP}{dr} + P - Q = \frac{d^2}{dz^2}\left(r\frac{d\Theta_2}{dr} + \Theta_2 - \Theta_1\right) = \frac{d^2\mu}{dz^2},$$

$$rR = \frac{d}{dr}\left(r\frac{d\Theta_2}{dr} + \Theta_2 - \Theta_1\right) = \frac{d\mu}{dr},$$

$$rT = -\frac{d}{dz}\left(r\frac{d\Theta_2}{dr} + \Theta_2 - \Theta_1\right) = -\frac{d\mu}{dz};$$

$$r^2S = -\frac{d}{dr}\left(r_2\frac{d\Psi_1}{dr} - r\Psi_1 - r^2\frac{d\Psi_3}{dz}\right) = -\frac{d\lambda}{dr},$$

$$r^2U = \frac{d}{dz}\left(r^2\frac{d\Psi_1}{dr} - r\Psi_1 - r^2\frac{d\Psi_3}{dz}\right) = \frac{d\lambda}{dz} \quad . \quad . \quad . \quad (13).$$

These conditions are required by Statics, and they cover the whole of the statical requirements.

If the stresses and strains follow Hooke's Law, we obtain the following independent conditions :

$$(1+\sigma)\left\{\frac{d^2Q}{dz^2} + \frac{1}{r}\frac{dR}{dr} - \frac{2}{r}\frac{dT}{dz}\right\} = \sigma\left(\frac{d^2}{dz^2} + \frac{1}{r}\frac{d}{dr}\right)\left\{P + Q + R\right\},$$

$$(1+\sigma)\left\{r\frac{dQ}{dr} + Q - P\right\} = \sigma r\frac{d}{dr}\left\{P + Q + R\right\},$$

$$\frac{dS}{dr} - \frac{S}{r} = \frac{dU}{dz} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14).$$

These are the necessary and sufficient conditions for the elastic relations.

If we proceed to find the statical stress which is consistent with Hooke's Law, we combine the two sets of conditions. We may write

$$P = -\frac{1}{r}\frac{d\mu}{dr} + \frac{1}{r^2}\mu + P'$$

whence we must have from (13)

$$Q = -\frac{d^2\mu}{dr^2} + \frac{1}{r}\frac{d\mu}{dr} - \frac{1}{r^2}\mu - \frac{d^2\mu}{dz^2} + r\frac{dP'}{dr} + P'.$$

Using now the second set of conditions (14), we find

$$r^2\frac{d^2P'}{dr^2} + 3r\frac{dP'}{dr} = \left(r\frac{d}{dr} + 1 + \sigma\right)\left\{\frac{d^2\mu}{dr^2} - \frac{1}{r}\frac{d\mu}{dr} + \frac{d^2\mu}{dz^2}\right\}$$

and

$$\frac{d^2}{dz^2}\left\{r\frac{dP'}{dr} + (1-\sigma)P\right\} = \left(\frac{d^2}{dz^2} - \frac{1-\sigma^2}{r^2}\right)\left\{\frac{d^2\mu}{dr^2} - \frac{1}{r}\frac{d\mu}{dr} + \frac{d^2\mu}{dz^2}\right\},$$

giving two equations connecting P' and $\frac{d^2\mu}{dr^2} - \frac{1}{r}\frac{d\mu}{dr} + \frac{d^2\mu}{dz^2}$.

If each of these quantities is null, the stress is independent of the elastic constants of the material.

The general case where the stress is independent of the elastic constants seems worthy of consideration. The distribution of the stress would in this case be geometrical, but the strain would depend on the elastic constants.

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XI. The presence of Maxillulæ in Larvæ of Dytiscidæ.

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The Dytiscidæ, a family of commonly occurring aquatic beetles of exceptional voracity in both the larval and adult state, are of considerable general interest, particularly owing to a singular adaptation of the mouth parts, by which the larvæ of these creatures are enabled to suck the juices of their prey. It is the purpose of the present communication to point to the existence, in the mouth parts of some at least of these larvæ, of a pair of minute processes which are probably homologous with the maxillulæ, or rudimentary oral appendages, found in certain primitive insects.

The precise nature of the mouth opening of the larva of *Dytiscus marginalis*, the most well-known member of the group, hitherto a matter of conjecture, has recently received detailed treatment at the hands of Rungius (**1**), who points out that the entrance to the mouth remains permanently closed by the interlocking ridges on the upper and under lips, since there are present no muscles adequate to the unclasping of these firmly united parts. In that case the larva of this species feeds entirely by means of the canals which conduct the juices of the victim from hair-fringed openings on the tips of the mandibles to the mouth cavity (*Fig.* 1, *f*). The distal portion of each canal seems to lie within the mandible

(*Fig.* 1, *a*), but in reality it is merely a deep groove on the surface, the opposite margins of this furrow being closely approximated but not united. The proximal region leading from the opening at the base of the mandible

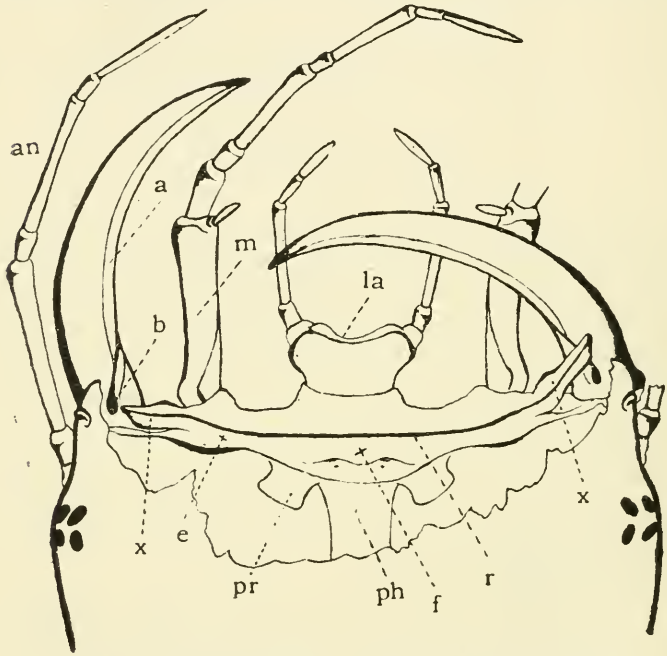

Fig. 1. The mouth parts of the mature larva of *Dytiscus marginalis* seen from above. Labrum and clypeus removed.

a, left mandibular canal; *an*, left antenna; *b*, basal opening of left mandibular canal; *e*, ventral wall of duct leading from mandible to mouth cavity; *f*, the mouth cavity; *la*, the labium; *m*, the left maxilla; *ph*, the pharynx; *pr*, backward process of mouth cavity; *r*, interlocking ridge on ventral side of mouth opening; *x*, processes homologous with maxillulæ, the right process raised from its normal position. × 11.

(*Fig.* 1, *b*) to the mouth cavity is formed of two opposed grooves situated respectively on the epipharynx and on the ventral surface (*Fig.* 1, *e*) of the mouth. These grooves are held closely in contact by the interlocking mechanism (*Fig.* 1, *r*) and can be regarded as somewhat produced angles of the mouth cavity.

For some little distance the ventral wall of the duct leading away from the base of the mandible is formed by a strong process, which with a little pressure can be bent forwards (*Fig.* 1, *x*). However, it is never everted naturally, as there is no joint at its base, and the ventral interlocking ridge (*Fig.* 1, *r*) of the mouth is continued without interruption along its antero-superior border. I regard each of these structures (*Fig.* 1, *x*) as a modification of a free anteriorly directed process, and by reason of their position with respect to the mandibles and maxillæ, I am inclined to include them with those similarly situated processes found in apterygote and in certain of the more primitive winged insects, and variously referred to as "*superlinguæ*" (Folsom) or "*maxillulæ*" (Hansen). Each of these possible maxillulæ is a simple, well chitinised, acute, three-sided process, with one border, as has been mentioned, adapted to interlock with the ridge on the upper lip. These parts were not materially different in a young larva under three-quarters of an inch in length.

An examination of four species of dytiscid larvæ, all of which could be referred with more or less certainty to the genus *Ilybius*, revealed the existence, in these species also, of certain structures comparable to maxillulæ. These were soft lobes (*Fig.* 2, *x*) which, present one on each side of the hypopharynx, normally reposed against slight depressions on the inner side and at the base of the mandibles. Each was a delicate, conical process, somewhat shrunken, or even collapsed, in preserved specimens. In these larvæ the mouth is not so perfectly closed as in *Dytiscus*, and it is not unlikely that the foregoing process represents the earlier condition of the maxillular structure described in *Dytiscus*, the strengthening and lateral depression of which subserve the increased efficiency of the interlocking arrangement.

Dugès (**2**), in describing the larva of *Cybister fimbriolatus*, Say, called attention to a small process at the base of the mandible:—" A la base de la mandibule on " aperçoit un petit corps paraissant cylindrique, courbé " sur lui-même et arrondi à l'extremité où il semble " papuleux et que nous croyons être le représentant des " lobules maxillaires." Dugès was evidently under the impression that in this larva there remained nothing of

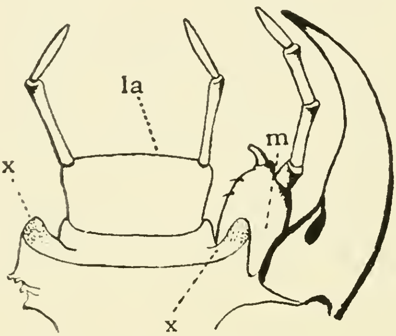

Fig. 2. Mouth parts of larva referable to the genus *Ilybius*, seen from above.

la, labium ; *m*, right maxilla ; *x*, processes homologous with maxillulæ. × 40.

the maxilla but its palp, and so suggested that the above body at the base of this palp might represent the galea and lacinia of the maxilla, but the nature of the maxilla in the larvæ of other genera of the *Dytiscidæ* renders such an interpretation a very doubtful one. Meinert (**3**) figures the mouth parts of an undetermined exotic species of *Cybister*, recording the presence of a similar body which he emphatically points out can have no connection with the maxilla, and which he refers to the mandibular segment. However, Meinert also notes that the ventral portion of the canal leading from the mandible to the mouth cavity projects strongly, and from his figure it would seem very similar to the corresponding part in *Dytiscus marginalis* (*Fig.* 1, *x*), hence I am inclined to regard the process described by both these authors as a palp-like projection of a still larger process, indicating, perhaps, the occurrence of a more primitively constituted maxillular rudiment in the larva of *Cybister.*

The investigation of the mouth parts of various other genera was not possible owing to lack of material, but it is hóped to extend the above limited observations during the coming season, and also if circumstances permit to inquire into the developments of these parts. Moreover, certain features observed in the imago of *Dytiscus marginalis* suggest that the structure of the adult mouth parts may throw some light upon the question of the existence of maxillulæ in the *Dytiscidæ.**

* In the current issue (vol. 57, part 4) of the *Q. J. M. S.* appeared a carefully illustrated memoir, "The Mouth-Parts of Some Beetle Larvæ (Dascillidæ and Scarabæidæ), with especial reference to the Maxillulæ and Hypopharynx," by Carpenter and MacDowell, who point out the existence of distinct maxillulæ in the larvæ of *Helodes* and *Dascillus.* These authors have also found it possible to detect corresponding structures, which are, however, almost completely merged into the labium, in larvæ of *Geotrupes* and *Phyllopertha.* The existence of maxillulæ in these Endopterygote insects is a fact of great interest, and strengthens the idea of their occurrence in the Dytiscidæ. However, direct comparison between the maxillular structures of these different types is not possible, owing to the highly modified condition of the larval mouth-parts in *Dytiscus* and its allies.—J. M.

REFERENCES.

(1) RUNGIUS, H. (1911). Der Darmkanal (der Imago und Larve) von *Dytiscus marginalis* L. *Zeit. für Wiss. Zool.*, Bd. 98, p. 179.

(2) DUGÈS, E. (1885). Métamorphoses du *Cybister fimbriolatus*, Say. *Ann. de la Soc. Ent. de Belg.*, vol. 29, p. 26.

(3) MEINERT, FR. (1901). Vandkalvelarverne (Larvæ Dytiscidarum). *D. Kgl. Danske Vidensk. Selsk. Skrifter, 6 Raekke, naturvidensk. og mathem.*, Afd. ix. 8, p. 403.

Manchester Memoirs, Vol. lvi. (1912), *No.* **12**.

XII. On the Interpretation of the Vascular Anatomy of the Ophioglossaceæ.

By William H. Lang, M.B., D.Sc., F.R.S.,

Barker Professor of Cryptogamic Botany in the University of Manchester.

(Received and Read, April 2nd, 1912.)

The affinities of the Ophioglossaceæ have long been a disputed question. At first classed with the Ferns, they were later compared with the Lycopodiales and Sphenophyllales. The work of Bower in examining and stating the latter view remains of importance, although, owing to the further evidence which has come to light, this investigator has recently changed his theoretical views. It now appears to be highly probable that the Ophioglossaceæ are Ferns and show special relationship with the extinct group of the Coenopterideæ (Botryopterideæ and Zygopterideæ). They also have features in common with the existing groups of the Osmundaceæ and Hymenophyllaceæ and these also exhibit affinities with the Coenopterideæ. The view that the Ophioglossaceæ are related to the Coenopterideæ was stated by Renault in 1875, and has been more recently expressed by Scott,[1] Bower[2] and other investigators.

This return to the earlier views as to the affinities of the Ophioglossaceæ has been brought about largely by the facts regarding the vascular relations of the sterile and fertile regions of the leaf and the structure of the sporangia. While weight has also been attached to the evidence obtainable from the general anatomy of the stem

[1] *Studies in Fossil Botany.* Plate II., Chap. XIV., p. 640.

[2] *Annals of Botany*, XXV. (1911), p. 296.

and leaf-trace, this has not been fully studied in the light of that of the extinct Coenopterideæ. Examination of a considerable number of species of Ophioglossaceæ has led me to regard the anatomy of the rhizome as best interpreted in the light of that of the Coenopterideæ and as affording important evidence in favour of a relationship between the two groups. Since it will be necessary to publish the results of my work on the three genera of Ophioglossaceæ separately, it appears advisable to make a brief general statement on the comparisons to which I have been led and on the chief grounds upon which they are based. Detailed figures will accompany the full papers, and only a few diagrams will be given here in order to make the comparisons clear.

The underground stem or rhizome in all the three genera of Ophioglossaceæ (*Helminthostachys*, *Botrychium*, and *Ophioglossum*) is normally unbranched. The presence of vestigial buds in the axil of every leaf of *Helminthostachys* was discovered by Gwynne-Vaughan, and I have recently found that similar vestigial buds are of constant occurrence in *Botrychium lunaria*.[3] The anatomical relations of the actual branches, which under special circumstances spring from these dormant buds, are of considerable interest. Apart from the particular relation of the bud to the leaf-trace or to the stem, however, the regular occurrence of axillary branching in these species is important as strengthening the comparison with the Zygopterideæ and Hymenophyllaceæ. Whether, as seems possible, the branching which occasionally occurs in *Ophioglossum* can be brought into line with the process in the other genera must be left an open question for the present; the branches are usually regarded as springing from lateral roots in the case of *Ophioglossum*.

[3] *Proc. Manchester Lit. and Philos. Soc.*, Feb. 20th, 1912.

The chief features of the vascular anatomy of the stem and leaf-trace must now be briefly described for the three genera of Ophioglossaceæ, *Helminthostachys*, which is in some respects the most instructive, being taken first. Most of the facts are common knowledge, but some additional ones will be added which aid in the interpretation of the vascular structure; it is with the interpretation rather than with the detailed description of the facts that this paper is concerned.

On following up the development of the stele of

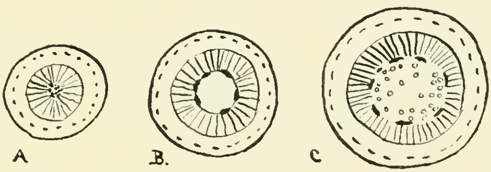

Fig. I. Transverse sections of steles showing the transition from the centrarch (A), through the endarch (B) to the mesarch (C) condition in a young plant of *Helminthostachys*. (Purely diagrammatic.)

[In this and the following figures the outer line represents the endodermis. The phlœm is indicated by a dotted line, and the protoxylem is black. The metaxylem is indicated by linear shading, but where the centripetal tracheides form a mixed pith they are individually indicated.]

Helminthostachys from the base of a sporeling plant or from the base of an axillary branch, the earliest stage is one with a solid xylem, the protoxylem elements being situated in the centre (centrarch) and the development of all the metaxylem centrifugal (*Fig.* 1A). Parenchymatous cells are usually mixed with the tracheides, and if they are numerous the stele may have a small pith from the first. In any case by the gradual increase in the number of parenchymatous cells in the centre of the xylem, a stage with a medullated stele is reached, the protoxylem elements being situated at the inner margin of the wood (endarch), (*Fig.* 1B). All the xylem at this stage is centrifugal but soon metaxylem elements appear to the inside of the protoxylem and the mesarch structure is established. This is found in rhizomes of various diameter and is independent of—and long precedes any appearance

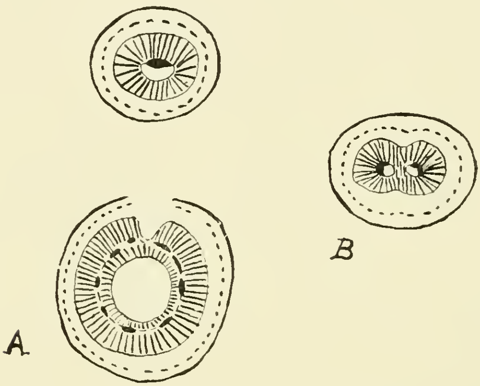

Fig. 2. A. Transverse section of small stele of *Helminthostachys*. The gap in the mesarch xylem is closing. The departing leaf-trace is endarch but has completed the centrifugal xylem on the adaxial side.

B. Leaf-trace further removed from the stele, showing the "clepsydroid" stage. (× 30.)

of—an internal endodermis. In small rhizomes the elements of the centripetal xylem may be scattered through the pith (*Fig.* 1C) but they are soon restricted to a peripheral position just within the protoxylem (*Fig.* 2).

The stele in strong mature rhizomes of *Helminthostachys* (*Fig.* 3) has a large pith around which comes the hollow cylinder of xylem ; phloem is present between the xylem and the external endodermis but there is no trace of internal phloem. A more or less complete internal endodermis, which will be considered further below, is often present in strong rhizomes. The xylem is mesarch, the protoxylem elements being situated nearer

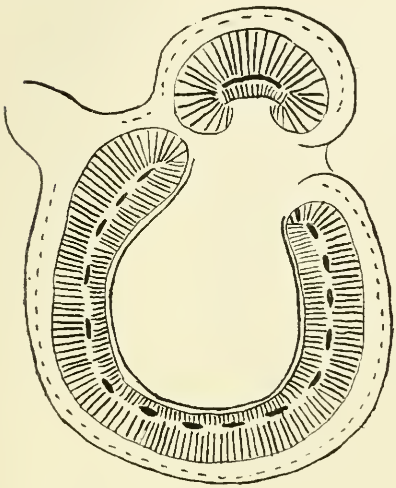

Fig. 3A.

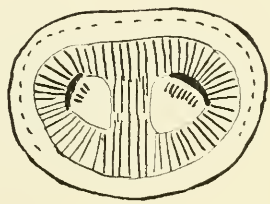

Fig. 3B.

Fig. 3. A. Transverse section of a large stele of *Helminthostachys* with internal endodermis. A mesarch leaf-trace, the centrifugal xylem of which is commencing to extend round adaxially is just departing. The disturbance in the external endodermis to the left is in relation to a vestigial bud.

B. The same leaf-trace in the clepsydroid stage. The persistence of the centripetal xylem at this stage brings out clearly the distinction between the mesarch condition and the adaxial completion of the xylem. *Ad.*, adaxial side of trace. (× 30.)

to the inner margin of the woody cylinder. All the xylem is primary but the elements of the metaxylem, especially of the centrifugal xylem, tend to be radially arranged. The centripetal xylem is more strongly developed on the dorsal side of the stele from which the leaf-traces arise than on the ventral side.

The mesarch xylem is usually altogether primary, but in rhizomes which bear lateral branches a considerable development of accessory xylem, which appears to be comparable to secondary thickening, may take place. This is due to active tangential divisions in the parenchymatous cells between the phloem and the xylem. The

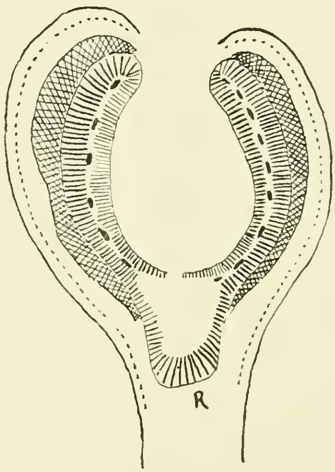

Fig. 4. Transverse section of a large stele of *Helminthostachys* without internal endodermis, which has borne a branch at the preceding node. In addition to the centripetal and centrifugal xylem a zone of accessory or secondary xylem (cross-hatched) has developed on the outside of the ordinary primary xylem. A root is being given off at *R*. (× 30.)

zone of accessory or secondary wood may either simply supply the branch or may be present all round the stele for some distance before the departure of the branch and persist for some distance beyond its departure (*Fig.* 4). Thus centripetal primary xylem, centrifugal primary xylem and (in exceptional cases) secondary xylem can be distinguished in *Helminthostachys*.

The departure of the leaf-trace from the stele and the structure of the trace present considerable variety in rhizomes of different size and age. From strong mesarch steles a mesarch leaf-trace may be given off (*Fig.* 3A). As this passes from the stele the centrifugal xylem of the trace often extends round adaxially and meets to form a complete ring; this encloses the centripetal xylem and some parenchyma. When the first division of the trace is about to take place a structure results which is of theoretical interest (*Fig.* 3B). In this a band of centrifugal xylem extends across and separates the two halves of the bundle; within each half is some parenchyma and the dying-out remains of the centripetal xylem, so that the structure is still mesarch. This stage has been distinguished by Bertrand and Cornaille by the appropriate name of the "clepsydroid trace," but has not been fully described.[4]

In smaller rhizomes (*Fig.* 2) the centripetal xylem usually disappears from the inside of the trace before its separation from the stele. The adaxial completion of the centrifugal xylem, however, takes place as the endarch trace departs (*Fig.* 2A) and the clepsydroid stage follows (*Fig.* 2B). In the case of very small rhizomes the departing trace may be almost as large as the stele remaining in the stem, and owing to the completion of the ring of xylem may present a general resemblance to the stem-stele. While an adaxial completion of the xylem of the leaf-trace is found in young plants as well as in larger rhizomes, it does not always take place, and in plants of all ages the departure of the trace and its dichotomy in the cortex may proceed without the closure being effected.

The structure of the stele and the mode of departure

[4] *Travaux et Mémoires de l'Université de Lille.* Tome X., Mem. No. 29, p. 179.

of the leaf-trace from it in rhizomes of *Helminthostachys* of various age and size offer many points of comparison with various Coenopterideæ. The mesarch structure of the xylem of the stele is comparable to what is described for *Zygopteris Grayi* and *Z. corrugata*, the centripetal xylem in *Helminthostachys* corresponding to the central xylem of the Zygopterideæ. The completion of the ring of centrifugal xylem in the trace and the clepsydroid stage of the trace are also comparable features. The structure of the stele and the relation of the leaf-trace to it in some young centrach rhizomes of *Helminthostachys* suggest comparison with *Botryopteris*, especially with *B. cylindrica*. The structure of stems with secondary xylem may perhaps be compared with *Botrychioxylon*. The general relations of the tissues in the stele of *Helminthostachys* affords probably the closest parallel in existing plants to the stele of *Zygopteris*.

The stelar structure of *Botrychium* has recently been discussed by Bower.[5] While confirming and adding to the facts which he records, his interpretation of the structure may be slightly modified and brought into line with that of the stele of *Helminthostachys* given above. In *Botrychium lunaria* the stele of the plant passes from a stage with a solid centrarch xylem to a condition in which a cylinder of endarch xylem surrounds a pith. This structure as a rule persists for a considerable length of the stem of the plant without any active secondary thickening taking place, and may be compared with a stage passed through rapidly in *Helminthostachys*. In *B. lunaria* tracheides may be developed in the pith. This was seen most strikingly in the case of a stem the apex of which had been destroyed while a branch had arisen

[5] On the Primary Xylem and the Origin of Medullation in the Ophioglossaceæ. *Annals of Botany*, Vol. XXV. (1911), p. 537.

lower down. (*Fig.* 5.) As Bower has shown tracheides commonly occur at the margin of the pith close to the inner side of the xylem ring in *Botrychium.* His account does not take the position of the protoxylem into consideration, but in the development of tracheides throughout the pith in *B. lunaria* it is clear that they are internal to the protoxylem. They thus correspond in position to the centripetal xylem of *Helminthostachys.* The primary xylem would in these cases be mesarch. This presumably holds also for the injured stem of *B. ternatum* with a mixed pith figured and described by Bower. Whether

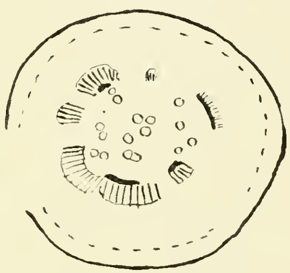

Fig. 5. Transverse section of stele of a young plant of *Botrychium lunaria*, which has borne a branch at the node below. Tracheides have developed scattered through the pith ; these constitute a centripetal xylem. (× 60.)

any of the tracheides or groups of tracheides that are sometimes found close to the inside of the cylinder of xylem in normal stems are centripetal is more doubtful ; there is no positive evidence of mesarch structure in a normal stem of *Botrychium.*

In the account in the preceding paragraph the first developed centrifugal elements of the xylem in *B. lunaria* are regarded as primary even though they may show a tendency to radial arrangement. It is not impossible, though difficult, to draw a line of division between the centrifugal primary xylem and the secondary xylem in this species. Such a distinction is practically impossible in some other species, such as *B. virginianum*, in which cambial activity proceeds at once and all the elements of the xylem are in centrifugally developed radial rows. The leaf-trace of *Botrychium* in endarch, and no adaxial completion of the xylem such as is described above for *Helminthostachys* occurs normally. It may however be pointed out in passing that if all the xylem in the stem of *B. virginianum* is regarded as secondary, this involves regarding the leaf-trace as also wholly composed of secondary xylem. Such an interpretation is not adopted in the analogous cases among Gymnosperms and Dicotyledons when secondary thickening supervenes early and makes a sharp distinction of primary and secondary xylem impossible.

Taking all the facts I have been able to ascertain from the literature and from the study of a number of species of this genus into consideration it seems justifiable to distinguish in the stem of *Botrychium* centrifugal primary xylem, and, in exceptional cases, centripetal primary xylem as well as secondary xylem. This brings the structure into line with the stem of *Helminthostachys*, the differences depending on the absence or poor development of the centripetal xylem and the regular and early supervention of secondary thickening in *Botrychium*.

The type of stelar structure which persists throughout the stem in the simpler species of *Ophioglossum* is readily related to that of specimens of *Botrychium lunaria* in which no secondary growth is evident and the leaf-gaps overlap. In *Ophioglossum* the stele consists of a network of separate collateral strands. The xylem of each strand is endarch and normally only centrifugal primary xylem is present. No marked secondary thickening is found. In a species of *Ophioglossum* collected in Ceylon the structure of which was typical a specimen was found bearing two lateral branches. As is usual in such cases the growth of the parent plant had been arrested. The study of the structure of the specimen (*Fig.* 6) revealed the existence of centripetal xylem, mixed with the parenchyma of the pith and apparently derived by the conversion of some of the medullary cells into tracheides. Thus, under exceptional circumstances, centripetal xylem forming a mixed pith may be developed in *Ophioglossum*, as has been seen above to be the case for *Botrychium*.†

Fig. 6. Transverse section of the stele of a plant of *Ophioglossum* which bore two buds. Short tracheides have developed throughout the pith forming a centripetal xylem. (×60.)

The occurrence of an internal endodermis in the stele of the Ophioglossaceæ and the view to be taken of the nature of the pith in this group have still to be considered. An internal endodermis is found in strong rhizomes of *Helminthostachys* and becomes continuous with the external endodermis at the leaf-gaps. If *Helminthostachys* be considered by itself the gradual development of the medullated stele as described above and the irregular occurrence of an internal endodermis in large plants

† In both cases the stimulus to the development of the tracheides in the pith may have been traumatic.

appear to justify the conclusion that the endodermal characters of the internal endodermis are due to independent specialisation of cells of a stelar pith near to the inner margin of the xylem ; in this case the endodermis could not be taken as proof of an intrusion of cortical tissues to form the pith of the stele. This view of the internal endodermis in *Helminthostachys* receives further support from the occasional development of a similar boundary to the pith of the root in this plant, and from the fact that the internal endodermis in the rhizome often abuts directly on elements of the xylem.

In the case of some species of *Botrychium* and *Ophioglossum* an internal endodermis continuous with the external endodermis at the leaf-gaps is present in the lower region of the young plants but is wanting in the older plant. At first sight the appearance of this internal endodermis in the young plants seems strong evidence of an intrusion of cortical tissue at the leaf-gaps. Bower, who has discussed this question at length,[6] provisionally accepts the endodermis as marking the limit between stele and cortex and interprets the pith in young plants of *Botrychium lunaria* as originally intra-stelar and later partly intra-stelar and partly intrusive. I venture to think that it is impossible to rest at this compromise in interpreting the stelar structure of the Ophioglossaceæ. The uniformity of plan of construction of the stele in the group makes it probable that one explanation of the origin of the pith must hold throughout.

A full discussion of the difficult morphological question of the intrusive origin of pith is impossible here, but some considerations may be mentioned which lead me to place more weight on the interpretation suggested by *Helminthostachys, viz.*, that the pith in the Ophioglossaceæ is not

[6] Bower, *Annals of Botany*, Vol. XXV. (1911).

intrusive and the internal endodermis not a tissue boundary between the stele and an intrusive cortex. It will be clear that this view fits with the progressive development of the stele of *Helminthostachys* and is consistent with the comparisons made between this plant and the Coenopterideæ. As regards *Botrychium lunaria* the study of a number of plants cut in complete transverse series from base to apex has shown considerable variety in the development of an internal endodermis. There may be no internal endodermis extending into the stele throughout the whole development, while in other cases in which appearances consistent with an explanation of "pocketing" or "intrusion" are found at the lower nodes the endodermal pockets are very irregular; as a rule they have no bottom and often their sides are incomplete. A well-developed pith is present below any trace of internal endodermis not only in sporeling plants but in the basal region of axiliary branches of *B. lunaria*. Further, the centripetal tracheids forming the mixed pith in *B. lunaria* (*Fig.* 5) developed in a young plant above a region where an internal endodermis was present, *i.e.*, in a tissue which on the theory of intrusion would be regarded as of cortical origin.

These facts are not conclusive, but they show that the presence of an internal endodermis in the Ophioglossaceæ cannot be taken by itself as proving intrusion of cortical tissue to form the pith. There is no evidence that this can be established directly by the relations of the tissues at the apex during development. The absence of any direct evidence of "intrusion of cortex" holds not only for the Ophioglossaceæ but for ferns generally, and, valuable as the concepts of "pocketing" and "cortical intrusion" have been in recent comparative work on the anatomy of ferns, the reality of the tissue changes they imply is unproved and is open to considerable doubt. Without entering into the wide morphological questions that this consideration opens up, it may be pointed out that, if the explanation of the stele of *Helminthostachys* and the progression in stelar structure in the Ophioglossaceæ here suggested proves to be correct, it has a bearing on the theory of the origin of solenostelic and dictyostelic structure in other ferns. If the structure of strong rhizomes of *Helminthostachys* with a complete internal endodermis has come about by elaboration of a protostele without any intrusion of cortex it suggests the possibility that the origin of the solenostele may also in some cases have been without actual "intrusion" of tissues into the xylem of the stele. If "intrusion of cortex" is only a metaphor it is not inconsistent with this view; if the concept means what it signifies it requires to be supported by developmental evidence.

The facts known regarding the stelar anatomy of the Ophioglossaceæ appear more consistent with the interpretation of the origin of a medullated stele and the progression towards solenostely given by Boodle[7] in discussing the case of the Schizaeaceæ[8] and stated as one of the alternative methods of origin of the solenostele by Gwynne-Vaughan.[9] They do not support the extreme view advocated by Jeffrey,[10] that the pith is always due to the intrusion of cortical tissues.

The critical study of the vascular anatomy of the stem and leaf-trace in the Ophioglossaceæ thus suggests

[7] *Annals of Botany*, XV. (1901). p. 410.

[8] The parallels between the Schizaeaceæ and the Ophioglossaceæ are extremely interesting. Both internal endodermis and groups of tracheides appear in the medulla of Schizaea.

[9] *Annals of Botany*, XVII. (1903), pp. 738, 739.

[10] *Botanical Gazette*, Dec., 1910, p. 401.

that the most natural interpretation is one which recognises an essential similarity in plan of stelar construction between the Ophioglossaceæ and the Coenopterideæ. The origin of the vascular structure of the Ophioglossaceæ by elaboration of a protostele and development of an intrastelar pith would have been parallel to, but independent of, that in the Osmundaceæ. When the specialisation of the extinct groups and the imperfection of our knowledge regarding them is borne in mind it seems inadvisable to suggest the direct derivation of the Ophioglossaceæ from any particular forms. It may be said, however, that the Ophioglossaceæ and Coenopterideæ appear to throw mutual light on one another as regards morphology and anatomical structure, and that the anatomical evidence supports the view that there is a real, though it may be a collateral, relationship between the two groups.

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XIII. On Search-Lights for the Mercantile Marine.

By HENRY WILDE, D.Sc., D.C.L., F.R.S.

(*Received and read May 7th, 1912.*)

The recent overwhelming disaster to the "Titanic" by collision with an iceberg induces me to bring before the Society, and indirectly to others interested in the application of electricity to navigational purposes, certain causes which have retarded its progress and are responsible for the deplorable event which is now engaging the attention and sympathy of the whole civilized world.

Forty-six years ago I announced before the Royal Society the discovery that quantities of magnetism and electricity indefinitely small would induce quantities of these forces indefinitely great.* This discovery was embodied by me in a generator of electricity and magnetism far surpassing in power any voltaic battery or machine heretofore produced, and was named by Charles Brooke, F.R.S, a "*Dynamo-electric Machine.*" †

It is common knowledge that this machine in various forms is utilised for producing electric light—the electro-deposition of metals, the transmission of mechanical power to great distances—and is an indispensable feature in wireless telegraphy.

One of my early applications of the dynamo-electric machine was the projection of a beam of electric light to illuminate distant objects for naval and military purposes.

* *Proc. Roy. Soc.*, 1866, vol. 15, p. 107. *Phil. Trans.*, 1867.

† *Proc. Roy. Soc.*, 1867, vol. 15, p. 409.

In 1873 my inventions were sufficiently developed to enable me to submit them to the Admiralty, as a protection against torpedoes, when, after lengthened trials at Spithead (1874-1875) by a joint War Office and Admiralty Committee, they were definitely adopted and a number of first-class battleships were equipped with search-lights under my direction.

In 1876 Admiral Sir Beauchamp Seymour, commanding the Channel Squadron, reported to the Lords Commissioners of the Admiralty as follows:—

> " 1. The Electro-Magnetic Machine, fitted to the
> " 'Minotaur' by Messrs. Wilde and Co., has now been
> " in use for seven months, and having thoroughly
> " tried it under all circumstances of wind and weather,
> " including fog, I am enabled to give my testimony to
> " its great value."
>
> " 2. I do not consider that a vessel blockading an
> " enemy's port, and obliged by circumstances to
> " remain at anchor, would be safe without it."
>
> " 3. It would be of the utmost use in a night
> " action, and in determining the character of a vessel
> " approaching the ship, carrying it by night. These
> " points have been amply tested in the Channel
> " Squadron since November last, when cruising in
> " company or at night quarters."
>
> " 4. For the ordinary purposes of navigation it
> " has also its advantages, as while passing through a
> " narrow channel by night a light can be thrown on
> " either shore; the amount of this, however, depends
> " much more than would be imagined on the state of
> " the atmosphere at the time."
>
> " 5. It is also extremely useful when vessels are
> " approaching or passing each other."

"6. As their Lordships are aware, the 'Parabolic "Reflector,' mentioned in your letter of 11th October, "1875, was not fitted on account of the expense; "but the Dioptric Lens seems, so far as I can judge "(not having seen the Reflector in use), to be all that "is required."

"7. With regard to its use for signalling purposes, "it has been used on several occasions, and the flashes "have been shown, both by the vertical ray and also "by obscuring and showing the direct ray of the "light alternately, on the same principle as Colomb's "Flashing Light, under which circumstances it has "been found very useful, as illustrated by the fact that "on the night of the 19th H.M.S. 'Black Prince,' "then distant six, and 'Resistance' four miles, readily "took in a signal directing them to part company and "proceed to Plymouth."

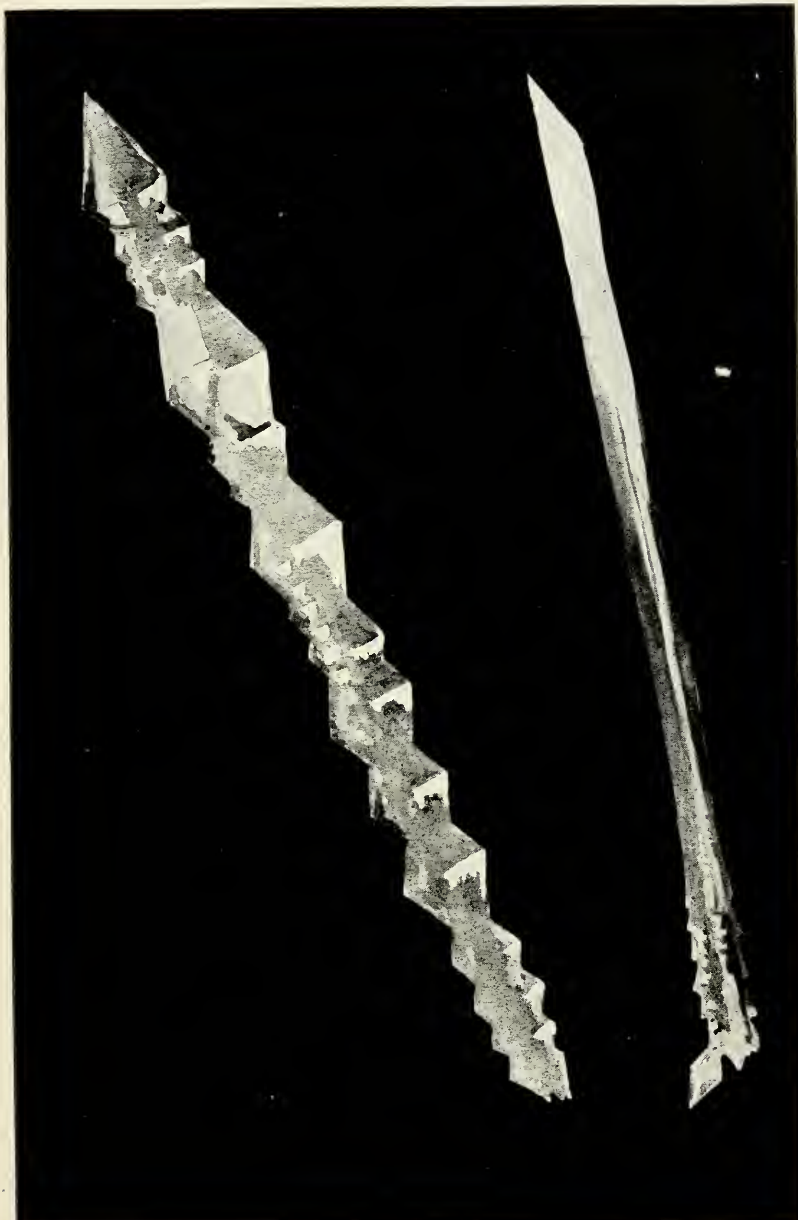
"8. I may conclude by saying that this Machine "is a most useful and valuable invention, and that I "should be very sorry to be without it in any "Squadron in which I may have the honour of "serving."

In 1882, the search-light was used with striking effect on the fortifications of Alexandria on the night before the bombardment by Sir Beauchamp Seymour, then Commander-in-Chief of the Mediterranean Fleet.

Following the ordinary course of prime discoveries and inventions, improvements were made (chiefly by foreign inventors) on my dynamo-electric machines and search-light equipment. Several of these improvements were of considerable merit, but could not be used without infringement of my patented inventions. Nevertheless, the Admiralty claimed the right, from the exigencies of the public service, to use them, but without making any compensation. Happily my inventions connected with the electro-deposition of metals brought me more than sufficient means to satisfy my moderate desire for wealth as a means of usefulness, and relieved me of the disagreeable necessity of presenting a humble petition of right to the High Court of Judicature for adjusting the differences between inventors and the Government under like circumstances.

The appropriation of my discovery and inventions was not, however, my only grievance against the naval authorities at Whitehall, for after establishing the value of search-lights in the Royal Navy, it appeared to me that the Mercantile Marine would also realize its advantages. A demonstration was, therefore, made at the works of the Pacific Steam Navigation Company at Birkenhead, where the light was displayed for the first time, and the shipping and lofty buildings on the Liverpool side of the Mersey were illuminated in bold relief. No sooner, however, were attempts made to establish the search-light on merchant ships than the Admiralty intervened and claimed the exclusive right to use the light, on the alleged ground that its brilliancy interfered with the navigation of other ships. This embargo remains in force to the present day, as will be seen from the evidence of Mr. Bruce Ismay at the recent inquiry of the American Senate Committee into the causes of the disaster to the "Titanic," at which he stated that none of the Atlantic liners were equipped with search-lights.

That the brilliancy of the electric beam interferes with the navigation of other ships is only a minor objection in comparison with its great advantages is evident from the fact that the search-light has been in constant use on the Suez Canal for some years, by which the carrying



Manchester Memoirs, Vol. lvi. (1912), *No.* **15**.

XV. The Smelt in Rostherne Mere.

By T. A. Coward, F.Z.S.

(*Received April 29th, 1912. Read May 7th, 1912.*)

The Smelt or Sparling, *Osmerus eperlanus*, is normally, during the greater part of the year, an inhabitant of salt water, but during the breeding season, from March to May, it frequents estuaries or ascends rivers into fresh water.

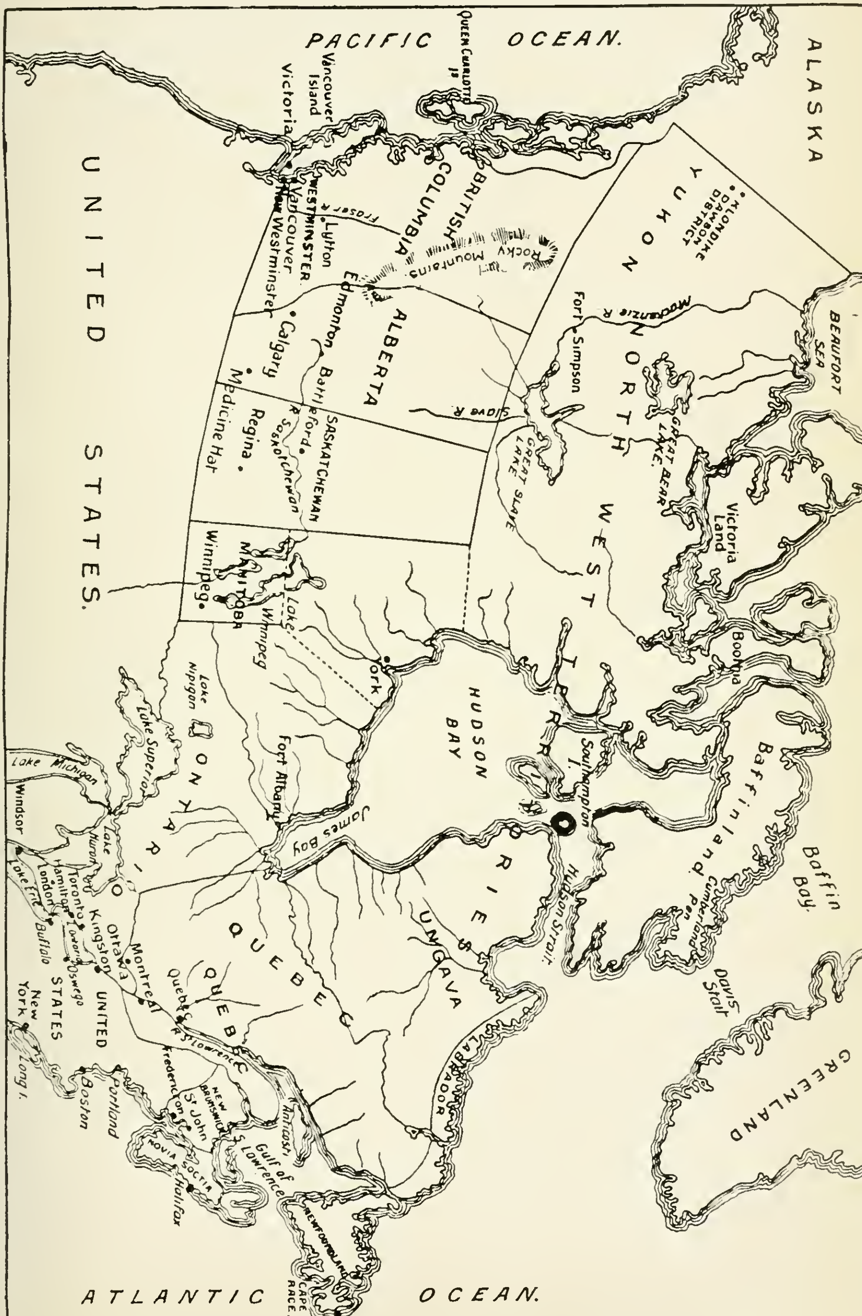
As a rule, however, it spawns in brackish water or but a short distance above the influence of the tide. It can, however, like other anadromous salmonoids, live in fresh water for a considerable period, and it has been successfully kept and even induced to spawn in freshwater ponds. It appears to be a permanent freshwater resident in some Swedish lakes, but in Britain it is only known in one water, Rostherne Mere in Cheshire.

The Smelt was known to be an inhabitant of Rostherne Mere in the early part of the 18th century, for Richard Brookes refers to it, under the heading of "Sprat or Sparling," in his "Art of Angling," published in 1740. Day also mentions Rostherne in his "British Fishes," but states that it was introduced. The origin of this assertion is uncertain, and there is no record of the introduction.

Early in the 19th century, I am informed, the Smelt was occasionally captured in the Mere, and I believe that it has been found in the stomachs of pike which were captured in the Mere. In February, 1895, I cut a number out of the ice and submitted them to the late Dr. Günther, but for some years prior to that date, and from then until the present year, I have only heard of it having been seen once. On April 4th I found two dead in the water at one side of the Mere; one of these is now in the Manchester Museum and the other in the Museum of the Liverpool University.

Day's statement that the fish were introduced by "Mr. Egerton" suggests that they were not in Rostherne so early as is shown by Brookes's record, and I do not place much faith in the remark. I believe that the fish have existed in the Mere since it was possible for them to ascend from the sea, or, in other words, prior to the building of the weirs. What originally caused them to run to Rostherne for spawning, and why they are not found in other Cheshire waters, is difficult to understand. We can only suppose that there are favourable conditions for their existence in Rostherne, as there are in the Swedish Lakes, which have enabled them to survive.

One peculiar characteristic of the fish has not been lost by its freshwater life. I carried the two dead smelts home in my handkerchief, which, afterwards, still smelt strongly of cucumber.


PACIFIC OCEAN.
ATLANTIC OCEAN.
ALASKA
UNITED STATES.
YUKON
KLONDIKE
DAWSON DISTRICT
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
UNGAVA
LABRADOR
NORTH WEST TERRITORIES
GREENLAND
Baffin Bay
Davis Strait
Baffinland
Cumberland Pen.
Boothia
Victoria Land
Southampton I.
Hudson Strait.
HUDSON BAY
James Bay
BEAUFORT SEA
GREAT BEAR LAKE.
GREAT SLAVE LAKE
Slave R.
Mackenzie R.
Fort Simpson
Rocky Mountains
Queen Charlotte Is
Vancouver Island
Victoria
Vancouver
New Westminster
WESTMINSTER.
Lytton
Fraser R.
Edmonton
Calgary
Battleford
R. Saskatchewan
Regina
Medicine Hat
Winnipeg
Lake Winnipeg
York
Fort Albany
Lake Nipigon
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Windsor
London
Hamilton
Toronto
Ontario
Kingston
Ottawa
Montreal
Quebec
Oswego
Buffalo
UNITED STATES
New York
Long I.
Boston
Portland
R. St Lawrence
Fredericton
St John
NEW BRUNSWICK
NOVA SCOTIA
Halifax
Anticosti
Gulf of S. Lawrence
NEWFOUNDLAND
CAPE RACE.
St John's

Manchester Memoirs, Vol. lvi. (1912), *No.* **16.**

XVI. A Note on the Submerged Forest at Llanaber, Barmouth.

By T. G. B. Osborn, M.Sc.,

Lecturer in Economic Botany in the Victoria University of Manchester.

(*Read May 7th, 1912. Received for Publication July 15th, 1912.*)

Some two miles north of Barmouth, on the Welsh coast, there may be seen at low tide on the foreshore about the village of Llanaber, the remains of a "submerged forest." My attention was first drawn to it when staying there in August, 1911, and on a visit in April of this year specimens of wood and peat were collected for examination. It had originally been intended to make a more detailed survey the following summer, but, circumstances having arisen which prevented this, the following note has been written.

Several "submerged forests" are known along the coast of Lancashire and Wales, *e.g.*, at the Alt Mouth, Llasowe, Penmaenmawr, Aberdovey, and Tenby. Those at the Alt Mouth and Llasowe have been described with some detail, and are stated to belong to the Post-glacial or Recent times.* There do not appear to be any reasons to suppose that the deposit at Llanaber is of very different age, though the floristic composition differs in some respects from the more northerly forest.

Barmouth stands at the mouth of the Mawddach estuary, and is mostly built upon steeply rising slopes of Cambrian sandstone. The railway station and a part of the town are built on an alluvial flat or raised beach. This runs north from the town as a strip of flat country on the landward side of which the hills ascend, while it is bounded on the shoreward side by a pebble storm-beach

* Morton, G. H., "Geology of the Country around Liverpool," 1897.

and in places low sandhills. At Llanaber Church the hills touch the foreshore for a few hundred yards, and are protected by an embankment upon which the Cambrian line runs. Immediately north of this the hills retreat again, and the railway runs to Dyffryn along alluvial flats, liable to become swamps in places during a wet season. Five miles north at Dyffryn, the line is about a

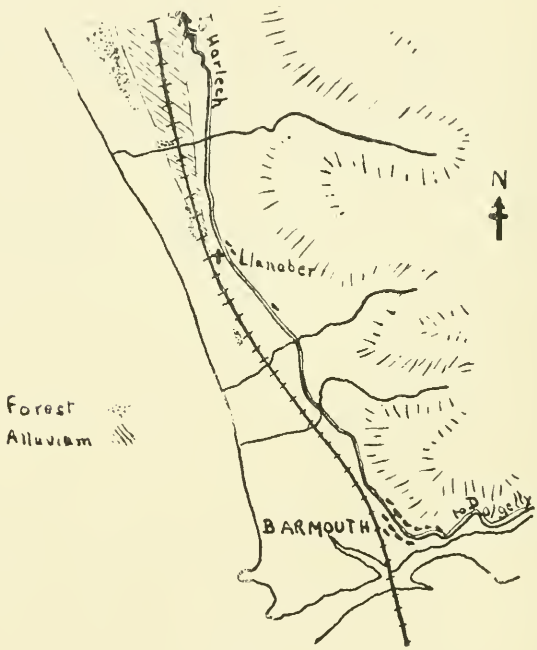


Fig. 1.

mile from the sea, with low-lying fields between it and the rather high sand hills that here line the shore.

Half a mile north of Llanaber Church there is exposed upon the foreshore at low tide a considerable area of stiff, whitish clay, which has the appearance of a typical underclay. It may be described * as fine and highly

* I am much indebted to my friend and colleague Dr. Hickling for his valuable help in the examination of the clays.

siliceous. Quartz grains predominate, while there are present zircon, tourmaline, rutile, and a little mica. With the possible exception of a few sponge spicules, it is remarkably free from organic matter. The quartz grains are rounded, and the general impression conveyed is that of a lake or rain deposit of boulder clay. While smaller organic remains are very rare, the antlers, and in some cases the skull and bones, of red deer (*Cervus elaphus*) have been obtained from this deposit. There is in the Manchester Museum a portion of a left antler, 19 inches long and $9\frac{1}{4}$ inches in circumference at the base, showing three tines which were obtained from these. Other specimens have been seen in various cottages in the vicinity, but it was not possible to secure them.

The clay last summer (1910) extended for some hundreds of yards along the shore, and was in places fully twenty yards wide, standing about a foot above the level of the sand (*Pl.* I., *Fig.* 1). During the course of the winter considerable erosion has taken place, and the seaward edge has been cut back.

Upon the clay the rhizomes and swollen stem-bases of the common reed (*Arundo Phragmites*) are to be found, of which the roots penetrate the upper part of the clay. This layer is only about an inch thick, and is succeeded by 6—9 inches of peat, largely composed of the decayed leaf-bases of a coarse grass or sedge, which form definite tussocks as the sea washes the smaller particles away. From washings of this peat, seeds of two species of *Carex*, and also a badly pressed tuberculated seed looking like a *Lychnis*, have been obtained.

Next above this, with their roots imbedded in the peat, and occasionally running into the clay, the trees of the forest layer are found. They appear to have been mainly birches; trunks of small trees may be seen lying prostrate in the peat, while the stools of others are frequent. Generally, only the base and roots of the trees are to be seen *in situ*, but in some cases 12—18 inches of the trunk stand erect, often without any bark. All the trees seen were birch, the bark of which, of course, is very characteristic. However, specimens of wood were collected from trunks, both with and without bark, and were examined microscopically, and again only birch wood was found.

Above the birch layer there is a further amount of *Arundo Phragmites*, the roots of which in some cases may be observed penetrating the rotten wood of the birch stumps (by Llanaber Embankment). Succeeding the reed layer there is a further peat zone, 12—18 inches thick, containing birch twigs and branches, also grassy leaves and reed-like stems. From washings of this peat a comparatively large number of fruits of a small sedge * (*Carex* sp.) were obtained, also "a fragment of *Sparganum* (?) and a broken *Potentilla* (?)" and numerous small galls. There were also found fragments of a small black beetle impossible to identify.

There is no sharp line of demarcation between this peat and an overlying layer of clay, but there is a gradual transition from pure to sandy peat and so to a coarse sandy clay, in all about 2 feet thick. On the top of the clay is a deposit of gravel and small stones. The stones are rather flat, angular, and do not show signs of being much waterworn, but having rather the appearance of re-deposited glacial pebbles. A microscopical examination of this clay shows it to be of the same general nature as the lower layer, but much coarser, the silica grains being much larger.

At the base, where there is much peaty matter in it, at least two species of diatoms (*Cymbella* [*cistula* ?] and

* I desire to express my thanks to Mr. Clement Reed, F.R.S., who kindly named these seeds.

Navicula [*viridis* ?]) were recognised ; also straight sponge spicules. In the purer overlying clay the same two diatoms, also a third (*Navicula* [*elliptica*] ?) were found, as well as sponge spicules.

The relation of the layers of peat and upper clays is well seen in a section at the mouth of a small stream, half a mile north of Llanaber Church (*Pl. II., Fig.* 7). The accompanying diagrammatic section (*Fig.* 2) will also help to explain it.

In conclusion, the probable history of this small forest may be interpreted somewhat upon the following lines.

At some date after the glacial period a tidal flat stretched to the north of where Barmouth now stands, somewhere about a mile wide. This beach is now below low-tide mark, but the alluvial flats mark its position. The daily rise of the tide became blocked by the accumulation of a storm-beach, and possibly a range of sandhills to the seaward. Behind this barrier there was left an area into which the Mawddach and other streams would drain, and which was probably flooded by the tides, much as Barmouth estuary is to-day. In this area then accumulated a fine silt, the under clay, which deposit was obviously laid down in fairly still water. Gradually the deposit became thicker, covering carcases of the red deer that were floating in the water. As this area was silted up it was colonised by the reeds, which doubtless fringed its borders. After the usual method of colonisation of a swamp, grasses and sedges followed the reeds, slowly building up a soil of sufficient depth to allow a birch scrub to get a foothold. This period of dry land was followed, at any rate locally, by a second and comparatively rapid submergence, for, in some places, *Phragmites*, rhizomes and roots are to be found growing in and upon the birch stumps. Accumulation of water behind the storm-beach would be sufficient to account for this, and a rise in the

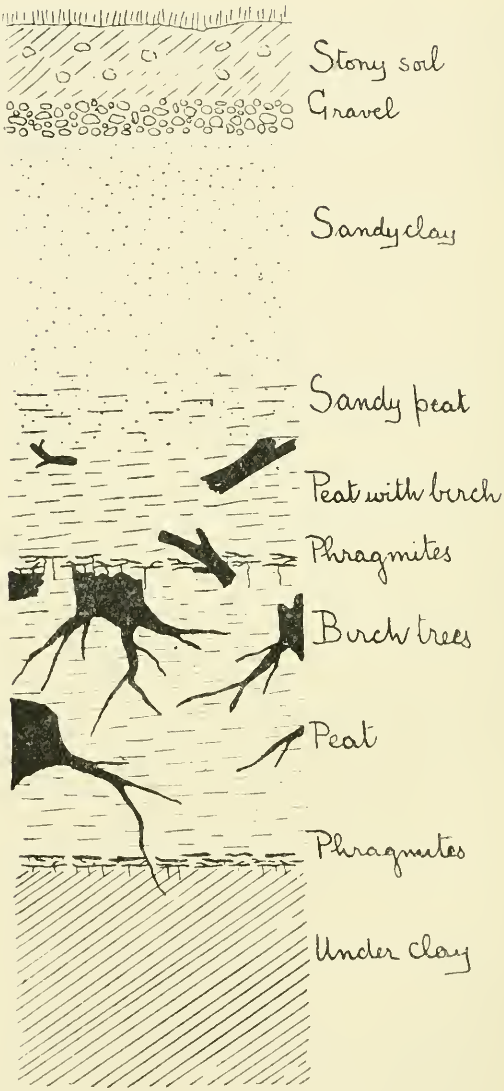


Fig. 2.—Diagrammatic section through forest bed.
($\frac{3}{8}$ths of an inch to 1 foot.)

water level of about three feet would probably be enough to kill the birches, and allow the reeds, which were probably growing all the time in the pools and water courses of the neighbourhood, to grow over the area. The presence of standing water, such as would be required by the *Phragmites*, probably did not last long, for we get a fairly thick (1-2 feet) deposit of peat, consisting largely of *Carex*. Following this there must have been a drop in the general land level behind the sea beach. This resulted in a submergence of the area, probably changing it into a fairly still fresh-water lagoon, giving the sandy clay deposits with fresh-water diatoms and sponge spicules.

So far the account of what probably happened in this small forest area is straightforward. The most difficult deposit to account for is that of the few inches of gravel above the sandy clay. The clay is so friable that it would be thought that any volume of water, sufficiently strong to deposit the stones, would have swept it and the underlying peat away. The most plausible explanation, which, however, in default of further examination is advanced tentatively, is that there must have been a drop in the land level of some 25 feet below the present low-water or high-tide mark.

Following this submergence there must have been a rise again to the present level, and after that the area would be left much as it is to-day. The high-water mark was originally much further to seaward than it now is, for stumps of oak trees, about 2 feet in diameter, are to be seen on the alluvial flats. One such, that in August, 1911, showed only a few inches above the pebble ridge, at Easter, 1912, was fully exposed, while the stump occupying the centre of *Fig.* 2, *Pl. I.*, had been washed away. The general line of the beach has been shifted in some places as much as 8—10 yards during the winter of 1911-12.

PLATE I.

Fig. 1. View of underclay, with covering of *Phragmites* rhizomes from the shore. The peat and birch stumps are to be seen in the background. August, 1911.

Fig. 2. Oak stump on storm-beach. Half-way up the picture, on the extreme right, the top of a second oak stump can be seen. Note also the relative positions of the shingle and post and wire fence. August, 1911.

Fig. 3. Oak stump (the one on extreme right of *Fig.* 2), April, 1912. Note also the way in which the shingle has been carried back. The stump is 2 ft. 4 in. in height.

Fig. 4. Peat, with birch stumps. At the back towards the left a drain is seen cut through the upper peat. April, 1912.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

PLATE II.

Fig. 5. Showing peat overlying the clay, with birch stumps in the middle distance. April, 1912.

Fig. 6. View looking up stream, showing peat with overlying clay and gravel on the left. On the right a birch trunk can be seen in the bed of the stream. August, 1911.

Fig. 7. Exposure in side of stream, nearer the mouth than *Fig.* 6. Shows the peat and clay, also the band of gravel next below the stony soil. August, 1911.

Fig. 5.

Fig. 6.

Fig. 7.

XVII. On *Calamites (Calamitina) varians*, Sternb., var. *insignis*, Weiss.

By Mary A. Johnstone, B.Sc.,

(*Read May 7th, 1912. Received for publication July 15th, 1912.*)

Introduction.

An exceedingly well-preserved specimen of *Calamites (Calamitina) varians*, Sternb., var. *insignis*, Weiss, came into my possession recently, and considering that certain features are present in very beautiful detail, and that others differ very markedly from those in some recently described specimens, it seems to be worth recording if only for the sake of comparison.

Occurrence and Description of Specimen.

Occurrence. I collected the fossil from the quarry of the Bradford Brick and Tile Company (Yorkshire). It formed the core of one of the clay nodules which are abundant in the shale bands lying below the Better Bed coal.

General appearance. It is a shale cast of a short length of decorticated stem which has been crushed to a much flattened oval in transverse section. The whole of one face, the two rather crumpled edges and part of the other face are free from the embedding substance. Part of the encasing layer was missing; part was present and has been removed, thus affording a reverse of the features preserved.

The dimensions are as follows:—

Length	123 mms.
Average breadth	65 „
Greatest thickness	25 „

Internodes. The stem is divided up into nine internodes and is crossed by two lines of branch scars. The internodes are of very unequal length and the irregularity appears to be periodic: the interest attached to the stem lies partly in this. For reasons set forth below, *A* (*Plate*) is regarded as the top region. The lengths of the internodes, (1) being at the highest level, are:—

(1)	....	10 mm.	Incomplete Group.
(2)	....	10 "	
*(3)	....	11 "	
(4)	....	15 "	Complete Group.
(5)	....	10 "	
(6)	....	10 "	
*(7)	....	12 "	
(8)	....	25 "	Incomplete Group.
(9)	....	20 "	
Total length......		123 "	

It is evident:—

(*a*) That there are present one complete group of internodes, the upper members of a second, and the lower members of a third.

(*b*) That 1, 2, 3 and 5, 6, 7 constitute two similar sets, the lowest internode of each of which is a branch internode, and the other two are the shortest in the series.

(*c*) That, whereas the shortest sections stand *above* the branch level, the longest in each case is *below* it.

(*d*) That the short nodes are of uniform length.

(*e*) That there is an ordered sequence in the recurrence of the shortened internodes.

Surface Texture. I should judge the surface to be a reproduction of the exterior of the woody cylinder, and should identify as the only trace of cortical tissue present

* The branch scars lie in these sections.

the carbonaceous layer which is still adherent where the fossil has not been exposed to weathering. Where this clings, the sharp outline of the markings is obscured, and a smoother surface results. Microscopic preparations of fair-sized stems rarely show the cortex as retained: it has quite naturally broken away along the zone of soft, delicate tissue, which occupies the position assigned to cambium and phloëm.

In the long internodes, the markings have the form of very fine longitudinal striations distributed over the entire surface, and so uniform in character throughout that they cannot be regarded as wrinkles or cracks due to shrinking or splitting bark. Ridge and furrow alternate, but neither, as a rule, extends the full length of the internode. The outstanding part is usually of a very attenuated spindle shape, broader considerably in its wider part than the furrow, dying out gradually, and sliding as it were past the tapering ends of its neighbours. The identification from structural examples is easy. The ridges represent the secondary xylem broken up into long slender sections by the furrows of the softer tissue of the secondary medullary rays. From the absence of parallel-sided ridges, extending from node to node, we may conclude that in this species the secondary xylem extended at the periphery completely across the primary medullary rays.

The short internodes differ somewhat. Where the striations can be made out they are much broader than in the others; they are parallel-sided and unbroken throughout the length of the internode: the separating depressions are very narrow. The differences may be due to uneven preservation, but it is more likely that they indicate differences in the living plant: parts quite free from distortion are clear to observation.

The Nodal Lines. In marked contrast to the nodal constrictions of pith casts, the nodal line on the exterior of this woody cylinder is a ridge, *r* (*Plate*), along the top of which lies the chain of contiguous leaf-bases. The protuberance is the highest part of a slight and gradual bulging outwards of the upper internode of the two involved. The leaf-scars are so placed on it that they face slightly downwards as well as outwards, overhanging the lower internode to the extent of about 1 mm. in some places. At the branching nodes, the exact position of the nodal line is obscure.

Leaf-scars. Every node is furnished with its closely packed whorl of leaf-bases, and this was probably true also of the branch nodes. About twenty-five traces may be counted on the flattened face of the fossil, and its whole circumference must have produced at least fifty. Regarding each of these as representative of a vascular bundle of the axis, we should have in a woody cylinder, roughly computed at 4 to 5 cms. in diameter, an approximation of fifty protoxylem groups—not out of accord with the evidence of structural sections.

The scars of the leaves are elongated ellipses, *l* (*Plate*), with their ends touching each other. By piecing together the evidence of the best preserved scars, the following details may be assigned to a typical trace when complete :—

(*a*) The boundary is a rather sharply outlined rim which merges at the end of the oval with that of the adjacent scar. The rim has the appearance of being incomplete or broken down on its lower side.

(*b*) A sloping internal face leading from the crest of (*a*) gradually to the edge of

(*c*) which is a minute circular pit almost like a pinprick.

One type of oval or elliptical leaf, as seen in structural preparations, corresponds very satisfactorily with these surface features. As seen in many of the beautiful examples which have been figured, there is present in the leaf a central strand of vascular tissue associated with a more or less complete surround of delicate-walled cells. This fine-celled core is marked off from the rest of the leaf by the firm and prominent ring of melasmatic tissue. Undoubtedly this boundary line corresponds to the edge of our central pit, which was the line of passage of the leaf-trace into the secondary xylem of the stem. In the pit itself would lie the xylem, phloëm, and parenchyma (if any) of the leaf-trace, whilst the melasmatic ring of the leaf would be continuous with the corresponding tissue in the stem.

When decay of the plant set in and the leaves and branches fell away, it would be natural that the slender vascular strand with its weak ground tissue should break off, leaving a depression to be filled in by the mud in which the whole was embedded. This in turn has been removed and the cavity has again been left exposed. Beyond the bundle tract would lie the cortical parenchyma—against the area of the slanting surface (*b*).

Branch Scars. The lower branching node produces nine and the upper, eight branches. These numbers refer only to what are visible on a single flat face, and the probable total in each whorl would be about twenty, or rather less than half the estimated number of leaves. It is not possible to trace any regularity in the occurrence of branches relatively to leaf-traces.

The scars are crowded together, the boundary rim being common to each pair at the point where they touch.

The average measurements are :—

Longitudinal	6 mms.	in lower line.
Horizontal	8 „	
Longitudinal	7 „	in upper line.
Horizontal	10 „	

They therefore cover about half of the internode in which they emerge, whilst at the same time encroaching on that below.

The general appearance of a scar is that of a deep cavity, the centre of which lies much closer to the lower edge, the upper slope long and gentle, the lower short and abrupt. Within these broader outlines more minute details can be made out. In the best examples a definite area P^1 (*Plate*) is clearly separated from the remainder as the deepest region—its outline is nearly circular; it is steeply funnel-shaped; its edge is sharply cut off from the upper slope of the stem xylem and may be an upstanding ring. From this pit the slope is gradual to the top rim, which is narrow-edged and simple, projecting sharply and sloping away again into the surface of the short internode: there are no complications on this upper edge. It must be noted that the medullary ray markings of the internode curve over the rim, and are continued to the edge of P^1; they look exactly as if the branch had been resting against them and preventing their outward development. This feature is absent from the lower slope.

The lower edge of the scar is less simply outlined. One particularly well-preserved example shows what may be described as a secondary ridge—very narrow—on the lower rim, with a narrow trench on either side of it; this is also seen, but less distinctly, on other scars. The lower of the trenches is part of a wavy depression, *s - - - - s*, which runs, with accidental breaks, under the whole row; it may be the counterpart of that which is overhung by the ridge of leaf-scars. The upper of the two furrows may be the ellipse (or two ellipses) of the leaf-scars, distorted by the pressure of the branches. This supposition is strengthened by the occasional occurrence of fine punctuations, P^2, (*Plate*) in the upper furrow, very closely resembling the pits in the leaf-scars.

The final history of the branches was very likely that of the leaves—decay and removal complete before fossilisation. Dr. Scott suggests (1) that slender branches might have been branches of limited growth, comparable with the needle shoots of *Pinus*. The shoots belonging to these scars might reasonably have been of this description.

The interpretation of the markings described above can be obtained by reference to petrified specimens. The xylem of the branch—a continuation from below of the stem xylem—makes its way outwards in an upwardly slanting direction; tangential sections passing transversely through a branch near the cortex present a wood zone broader in the upper than in the lower border, its pith eccentric in situation. A strikingly similar appearance is seen in the eccentric scars of *Bothrodendron punctatum*, which Mr. Watson (2) asserted to be branch scars—an opinion which has been confirmed by the discovery of specimens in which the branches were still in attachment (3). The funnel-like pit at the base is the cavity left by the disorganised pith, which, as we know, tapered gradually to its junction with the stem pith. On the other hand, the sudden enlargement of the depression which opens out exterior to the rim of the pit must be explained by looking upon it as having been occupied not only by the pith, but by both pith and xylem of the branch. That this was so, and that the whole of the branch has been removed from this area, is clear from the exposure of the medullary ray markings on the surface of the scar.

The moulds of several of the scars have been preserved, and corroborate what the cast shows, leaving little doubt as to the nature of the organ which fitted into the scar. They may be described as consisting each of two truncated, rather irregular, cones, the smaller of which is seated on the section of the larger, without quite covering it ; the strip left outside the base is hollowed out slightly. The missing apex of the small cone would be the apex of the pith left in the pit, the cone itself standing for the pith of the branch where it is embedded in the deeper xylem of the stem. On the sloping sides of three of the small cones can be distinguished arrangements of ridges and furrows like those in the common pith-casts, one of which this is considered to be. The ridges represent medullary rays, the furrows vascular bundles.

The larger basal cone has replaced the complete branch, disorganised and removed from its loose connection with the outer secondary wood. The slight trench which sometimes exists at the junction of the two cones would fit over the raised rim of the pit. It may simply point to a line of breakage.

IDENTIFICATION OF TOP AND BOTTOM.

It is necessary to determine with as much certainty as possible which is the top and which the bottom of the cast, as the position of the branch scars relative to that of the short internode bears directly on theories regarding the functional significance of that internode.

It has been proved fairly clearly by evidence from structural examples that branches emerge from the external face of the secondary xylem at a slightly higher level than the nodal line, leaf-traces practically at the level of the nodal line. It has been shown that the line *s - - - - s* (*Plate*) is probably the line of the leaf-scars belonging to the branch node. If this were quite conclusively proved, it would be sufficient to settle the question. But apart from this possibly doubtful evidence, there is something to guide us in the shape of the scars themselves. The Manchester Museum collection includes several fine preparations showing the microscopic structure of branches cut in transverse section near their points of emergence. Others are figured by Williamson and Scott. Examination of a series of longitudinal stem sections shows that at certain depths near the surface, the wood of the branch is developed unequally round the pith, the greater amount occurring on the *upper* side of the branch. The branch scars in the fossil are true to this type; the deepest part—that which is presumably the pith centre—is markedly eccentric, and lies nearer the nodal line to which the branch belongs. Again, in several of the *Calamites* figured by Stur (*see* below), the scar-bearing branches are still attached to their parent stems, and there can be no possible dispute about which is the basal region—in all of them the short internodes lie above the branch node, as I place them in the Bradford specimen. Accepting these three points as dependable evidence—the position of the line of leaf-scars below the branch scars, the eccentricity of the umbilicus, and the similarity to other branching stems of undoubtedly correct interpretation—I conclude that *A* (*Plate*) is the upper level of this stem.

Interpretation of Variation in Length of Internodes.

That the internodes in Calamitean stems may vary in length in any one specimen, and that there may be a periodicity in that variation has been noted and figured by several writers. Except in the last of the instances referred to below, no generalisation as to occurrence and function has been arrived at.

Williamson (4) mentions two *Calamites*, in one of which every 5th internode is short, and in the other every 8th. He expresses his inability to correlate these variations with any known external features, but suggests the possibility of their being of *specific* character.

Stur (5) figures several most instructive examples of Calamites, but does not enter into discussion of the grouping of internodes. Some of the figures, as placed, are inverted, but the true lower boundary is quite clearly indicated in some of them by the subtending leaf-bases, in others by the direction of growth of the younger branches. Amongst those which may be relied on as evidence to show whether short internodes lie above or below the whorl of leaf-scars, are those quoted below. *Pl.* II., *Fig.* 4, is clearly inverted ; *Pl.* II., *Fig.* 5, is almost certainly in the same position ; *Pl.* II., *Fig.* 3, is correctly placed ; *Pl.* V. and *Pl.* XI. are specially valuable. In these the branch bearing the whorls of branch scars is itself still in connection with an older axis : we can thus be quite certain about the relative positions of its parts. In all of the above, without exception, the abbreviation of internodes appears either in the internode in which the scars lie or in those above it : the internode below is always comparatively long. Reference is made to them as affording confirmation of the opinion as to which is top and which is bottom of the Bradford specimen.

Incidentally the last two specimens also illustrate the fact that the same plant bore its smaller branches or twigs in whorls, whilst the larger branches were sparsely and irregularly scattered over the parent axis. That is to say, Calamitina and Styocalamites might represent different orders of branching in a single plant rather than different groups of species.

Zeiller (6) in *Pl.* LVII., *Fig.* 1, of *Calamites Goepperti*, shows a long internode below, and at least two short ones above the branch internode; it is probable that the base is correctly indicated.

Kidston (7) gives a well-preserved cast of *Calamites (Calamitina) varians*, Sternb., var. *inconstans*, together with a table of measurements:—

	Internode.	Measurement in mms.	
	1	8·50	Period IV.
	2	5·	
	3	6·50	
	4	5·50	
	5	4·50	
	6	5·	
	7	3·	
	8	4·	
	9	3·50	
	10	3·	
	11	3·	
Scar internode	12	**7·**	
	13	6·	Period III.
	14	8·50	
	15	8·	
	16	8·	
	17	7·50	
	18	7·50	
	19	7·	
	20	5·	
	21	4·50	
	22	4·	
	23	3·50	
Scar internode	24	**7·50**	
	25	8·	Period II.
	26	11·	
	27	12·	
	28	12·50	
	29	12·	
	30	11·50	
	31	11·	
	32	10·50	
	33	8·50	
	34	9·50	
	35	6·50	
	36	5·	
Scar internode	37	**9·50**	

	Internode.	Measurement in mms.	
	38	19·	Incomplete Period I.
	39	22·50	
Lowest internode	40	17·	
	Total	321·50 mms.	

From this table we see to be true of each period :—

(*a*) That the shortest interval always succeeds the branch internode.

(*b*) That in the 3rd and 4th periods there are four or five very short internodes just above the branch line.

(*c*) That the scar internode itself is shorter, in two out of three cases, than the top one of the preceding period.

(*d*) That the top internode of each period is shorter than that below it.

(*e*) That there are irregularities in increase and decrease which may be due to fluctuating conditions of supply.

Summarising—the minimum length occurs immediately above the branches ; there is a gradual increase (usually slower at first) up to the maximum in the last internode but one ; the internode below the row of scars is in two out of three cases less than the maximum, but greater than the branch node ; there is an abrupt drop from this last to the minimum.

Kidston (8) reproduces a fine stem of *Calamites Sachsei*, Stur. (*Pl.* XIII., *Fig.* 1.) Each of its two rows of branches is supported by a long internode, and one of them shows plainly two short lengths placed above the branches.

In his paper communicated to the Linnean Society of London in 1909, Mr. Horwood (9) describes two pith casts of *Calamites* (*Calamatina*) *Schützei*, Stur, and includes for comparison the results of a series of observations on the stem internodes and leaf sheaths in recent Equiseta. Both casts show the periodical appearance of a shortened member at every 5th (or 6th) interval. One table of measurements is given below, the other is similar. For convenience of reading and comparison with other tables, I have inverted it.

Number.	Position on Stem.	Length in mms.	Period.
D	21	5·2	V. Incomplete.
C	20	5·2	
B	19	3·8	
A	18	**1·9**	
D	17	8·2	IV. Complete.
C	16	5·7	
B	15	4·0	
A	14	**1·9**	
E	13	7·1	III. Complete.
D	12	5·8	
C	11	5·2	
B	10	4·1	
A	9	**1·9**	
E	8	5·5	II. Complete.
D	7	5·2	
C	6	5·2	
B	5	3·5 to 3·8	
A	4	**1·6** to **1·9**	
E	3	6·3	I. Incomplete.
D	2	7·8	
*C	1	4·7	

Mr. Horwood says, "There is a noticeable increase, regular and gradual, in each period, commencing at the smallest internode. *At the end of each period branches were borne*, indications of which may be seen on the specimen." . . . This would place the branches in D

* First internode from the base.

(or E). "The most striking feature is the uniform length (1·6 to 1·9 cms.) and *position of the short internode at the commencement of each period*. . . . Node A (the short internode) appears to serve the purpose of imparting additional strength to the stem owing to the weight of the branches above." This may mean that the required mechanical support was provided four or five internodes lower down than the node where the branching actually occurred. But it is also open to the interpretation that the branch node is regarded as being situated immediately above the short strengthening internode. This last idea seems to be in Mr. Howard's mind when he refers for comparison to Dr. Kidston's specimen (7) and remarks of it: "In length it is 321·50 mm., and contains two complete and three incomplete periods, with forty internodes, *and a short internode precedes each branch-bearing node*." This statement does not seem to agree with the table of measurements; the internode below each line of scars is certainly slightly reduced as compared with that on which it rests, but the markedly short sections lie immediately *above* the scar. The conclusion arrived at by Mr. Horwood is that the shortening of the internode precedes a new period of the plant's development, and that "its function appears to be to add strength to the stem by the occurrence of two consecutive strengthening nodes (with diaphragms) serving the purpose of a double support within a short distance."

INFERENCES.

It seems justifiable to accept the following facts as established by comparison of the Bradford specimen and the figures of Williamson, Stur, Kidston, and Zeiller :—

(*a*) That in certain species of Calamites, or in certain parts of individual Calamites, a recurrent cycle of internodes was correlated with the occurrence of whorls of branches. This phenomenon appears to be confined to those instances in which the branches are crowded together at one level, *i.e.*, in those included in the subgenus Calamitina. I have met with no examples, figured or in specimens, amongst the Encalamites or the Stylo-calamites.

(*b*) That each period or cycle showed, immediately *above* the node at which the branches arose, one or more very stunted internodes, and immediately *below* it a comparatively long internode, which might either be the longest, or second to the longest in the whole series.

Significance of Cycle. Mr. Horwood's opinion that the approximation of the diaphragms strengthens the stem against the strain of superposed branches cannot be considered as upheld by a fact which he apparently infers in his paper—that the branches spring from the node immediately above the short internode.

I would suggest that the mode of growth under discussion was not a purposive arrangement at all. It might, with greater likelihood, be a consequence arising from the disturbance of normal physiological conditions at a level where important morphological changes took place. It may very possibly have happened that the diversion of a great amount of food material outwards to the secondary members impoverished the supply available for the normal increase in the primary axis, and retarded growth in the neighbourhood of the branch whorl. The group of shortened internodes would have to be considered as a result of, rather than as a preparation for, the appearance of the branch system.

This explanation is what I regard as the best. It is quite consistent with the fact that the phenomenon is to be found only in those Calamites in which the branches are closely crowded at certain levels, and in which the disturbance of uniform growth is at its maximum.

REFERENCES.

(1) SCOTT, D. H. (1900). "Studies in Fossil Botany," p. 31.

(2) WATSON, D. M. S. (1908). "On the Ulodendroid Scar." *Manchester Memoirs*, Vol. 52, No. 4.

(3) RENIER, A. (1908). "Origine raméale des cicatrices ulodendroïdes du *Bothrodendron punctatum*." *Comptes Rendus*, 1908, I., p. 1428.

(4) WILLIAMSON, W. C. (1871). "On the Organisation of the Fossil Plants of the Coal Measures." *Phil. Trans.*, Vol. 161, p. 495, Pl. 27, Fig. 30.

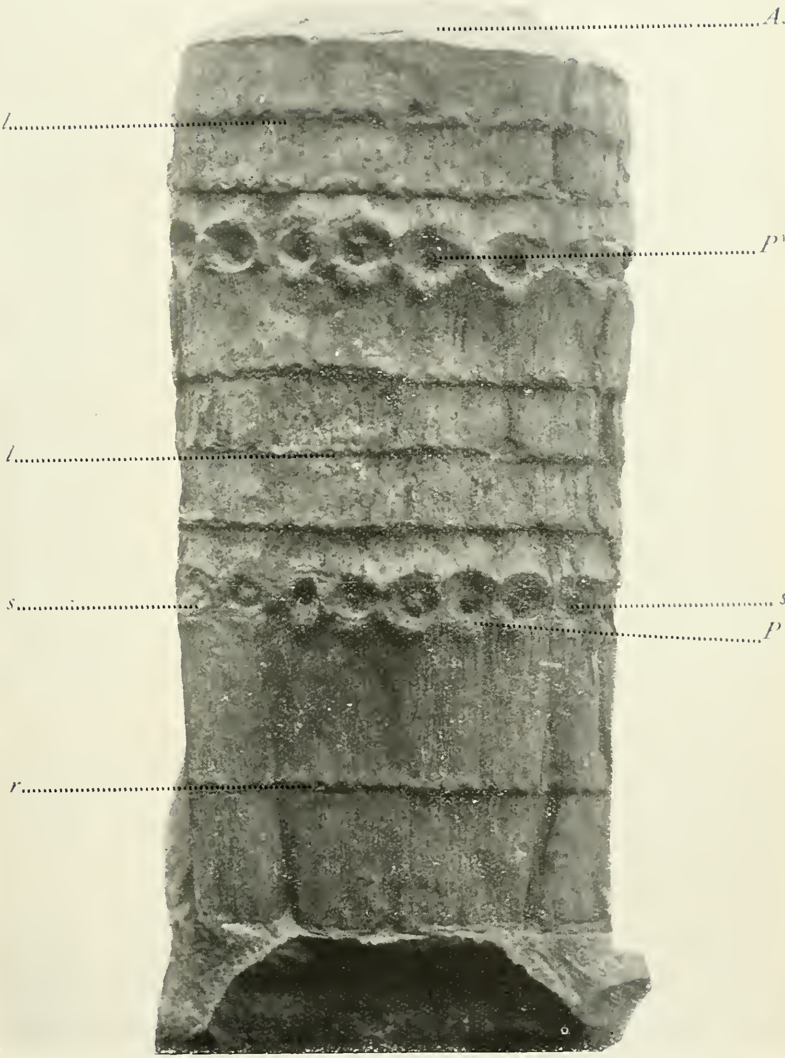
(5) STUR, D. (1887). "Die Carbon-flora der Schatzlarer Schichten. Abt. II. Die Calamarien." *Abhand. k. k. geol. Reichsanst. Wien*, Bd. XI., Abt. 2.

(6) ZEILLER, R. (1888). "La flore fossile du bassin houiller de Valenciennes. Etudes Gîtes Min. France." Paris.

(7) KIDSTON, R. (1889). "On the Fossil Plants in the Ravenhead Collection in the Free Library and Museum, Liverpool." *Trans. Roy. Soc. Edinb.*, Vol. 35, No. 10, Pl. I., Fig. 1.

(8) —— (1908). "Les vegetaux houillers du Hainault Belge." *Mém. Mus. Roy. Hist. Nat. Belg.*, T. IV., Pl. XIII., Fig. 1.

(9) HORWOOD, A. R. (1910). "On *Calamites Schützei*, Stur." *Journ. Linn. Soc.*, Vol. 39, p. 279.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PROCEEDINGS

OF

THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

General Meeting, October 3rd, 1911.

The President, Professor F. E. Weiss, D.Sc., F.L.S., in the Chair.

Mr. T. Wingate Todd, M.B., Ch.B., Demonstrator of Anatomy in the University of Manchester; Miss Mary A. Johnstone, B.Sc. (Lond.), Head Mistress of the Municipal Secondary School for Girls, Whitworth Street; Dr. A. A. Mumford, and Mr. Henry Ronald Hassé, M.A. (Cantab.), M.Sc. (Manc.), Lecturer in Mathematics in the University of Manchester, were elected ordinary members of the Society.

Ordinary Meeting, October 3rd, 1911.

The President Professor F. E. Weiss, D.Sc., F.L.S., in the Chair.

A vote of thanks to the donors of the books upon the table was passed; and Mr. C. L. Barnes drew attention to the 'Catalogue of Serials in the Library' which had recently been prepared. The following were amongst the recent accessions to the Society's Library: "*Die Kunstpflege der Wittelsbacher*," by

S. v. Riezler (4to., München, 1911), "*Wissenschaftliche Richtungen und philosophische Probleme im XIII. Jahrhundert*," by G. F. v. Hertling (4to., München, 1910), and "*Verlags-Katalog*" (8vo., München, 1911), presented by the K. B. Akad. Wissenschaften, München; "*Electrolytic Bleaching and the Manufacture of Hypochlorites by Electricity*," by E. Reuss (12mo., Leeds, 1911), presented by the Author; "*Sur la Structure et les Propriétés des Rayons Magnéto-cathodiques dans un Champ uniforme*," by M. Gouy (4to., Paris, 1911), presented by the Author; "*Handbook of American Indian Languages*," Pt. I., by F. Boas (8vo., Washington, 1911), presented by the Bureau of American Ethnology; "*Magnetic Observations made at...Bombay, 1846-1905, and their discussion*," Pts. I. and II., by N. A. F. Moos (fol., Bombay, 1910), presented by the Government Observatory, Bombay; "*Preliminary Report on a Visit to the Navaho National Monument, Arizona*," by J. W. Fewkes (8vo., Washington, 1911), and "*Indian Tribes of the Lower Mississippi Valley*," by J. R. Swanton (8vo., Washington, 1911), presented by the Bureau of American Ethnology; "*Geology of an Area adjoining the East Side of Lake Timiskaming...*," by M. E. Wilson (8vo., Ottawa, 1910), presented by the Geological Survey of Canada; "*Astrographic Catalogue, 1900·0, Oxford section, Dec. + 24° to + 32°*," vol. 7, prepared under the direction of H. H. Turner (fol., Edinburgh, 1911), presented by the University Observatory, Oxford; "*The Progress of Physics during...1875-1908*," by A. Schuster (8vo., Cambridge, 1911), presented by the Author; "*Antiquities of the Mesa Verde National Park Cliff Palace*," by J. W. Fewkes (8vo., Washington, 1911), and "*Indian Languages of Mexico and Central America*," by C. Thomas and J. R. Swanton (8vo., Washington, 1911), presented by the Bureau of American Ethnology; "*The Chattanooga Campaign...*," by H. M. Fitch (8vo., n. pl., 1911), and "*Wisconsin Women in the War between the States*," by E. A. Hurn (8vo., n. pl., 1911), presented by the Wisconsin History Commission; "*Finland: The Question of Autonomy and Fundamental Laws*," by N. D. Sergêevsky, transl. by V. E. Marsden (8vo., London, 1911), presented by the Translator; "*Nordiske Fortidsminder udg. af det...Oldskriftselskab*," Bd. II., Hfte 1 (fol., Kjøbenhavn, 1911), presented by the Kgl. Nordiske Oldskriftselskab, Copenhagen; and "*Investigation of the Motion of Halley's Comet from 1759-1910*," by P. H. Cowell...and A. C. D. Crommelin... (fol., Edinburgh, 1910), presented by the Royal Observatory, Greenwich.

New exchanges have been arranged with Teyler's Godgeleerd Genootschap (*Verhandelingen*), Haarlem; the Society of Chemical Industry (*Journal of*), London; *The Micrologist*, Manchester; and the University Observatory (*Contributions*), Princeton, New Jersey, U.S.A.

THE PRESIDENT gave an address on "**Researches on Heredity in Plants**."

The paper is printed in full in the *Memoirs* (see President's Inaugural Address).

General Meeting, October 17th, 1911.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

Mr. W. H. JACKSON, formerly Professor of Mathematics at Haverford College, Pennsylvania, 77, *Clarendon Road, Manchester*; Miss LAURA START, Lecturer in Art and Handicraft in the University of Manchester, *Moor View, Mayfield Road, Kersal, Manchester*; Mr. TOM WEST, B.Sc. (Manc.), Chemist and Metallurgist, *101, Spring Bank Street, Stalybridge*; Mr. D. THODAY, M.A., (Cantab.), Lecturer in Plant Physiology in the University of Manchester; Mr. Peter SANDIFORD, M.Sc. (Manc.), Ph.D. (Columbia), Lecturer and Demonstrator in Education in the University of Manchester; and Mr. J. N. PRING, D.Sc., Lecturer and Demonstrator in Electro-Chemistry in the University of Manchester, were elected ordinary Members of the Society.

Ordinary Meeting, October 17th, 1911.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was given to the donors of the books upon the table.

Mr. FRANCIS NICHOLSON, F.Z.S., stated that he had recently become possessed of a most interesting letter written by John Dalton shortly after he had become a resident in Manchester, and before he joined this Society on which he was afterwards to shed so much lustre.

This letter appears to have been known to Dr. Lonsdale, for it is quoted by him in his life of Dalton in "The Worthies of Cumberland," but perhaps it has not really lessened its interest, for Dr. Lonsdale did not print it exactly verbatim, and, moreover, he split it up so that portions of it are in three different chapters. It is also reproduced in Roscoe's "Life of Dalton," but again in separate parts.

The letter is dated in Quaker fashion, "2nd mo. 20th 1794," and is closely written on three pages of foolscap, the four concluding lines, the signature, and the address being on the fourth page. Elihu Robinson, of Eaglesfield, near Cockermouth, to whom it is addressed, is the person to whom Dalton owed most in his early intellectual development. Like Dalton, he was a Friend, and as he is styled "Dear Cousin" was presumably a relation of Dalton's.

The letter opens with an account of the "Manchester Academy," now "Manchester College," Oxford, then in Mosley Street, where Dalton, who had been appointed in 1793, was Tutor in Mathematics and Natural Philosophy. Many of the persons interested in the Academy were founders and early members of this Society, and it is mostly owing to them that Dalton was proposed and elected to be one of its members. The first paper he read before the Society—one on colour blindness—is foreshadowed in this letter, which contains, probably, the earliest account of that peculiarity of vision.

On October 3rd, 1794, John Dalton appeared as a member of the Society, and on the 31st of the same month made his scientific debut by reading a paper entitled "Extraordinary Facts relating to the Vision of Colours."

Mr. Nicholson thought that this interesting relic of perhaps the greatest man who ever belonged to this Society should be preserved in the Society's House, and he generously presented it to the Society.

Mr. H. J. WOODALL, A.R.C.Sc. (Lond)., read a paper on "**Mersenne's Numbers.**"

The paper is printed in full in the *Memoirs.*

A resumé of a paper by Mr. S. HIRST (Brit. Mus. Nat. Hist.), entitled "**On a Collection of Arachnida and Chilopoda** made by Mr. S. A. Neave in Rhodesia north of the Zambesi," was given.

The paper is printed in full in the *Memoirs.*

General Meeting, October 31st, 1911.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

Mr. CHARLES F. BUTTERWORTH, *Waterloo, Poynton,* and Miss MARGARET COLLEY MARCH, M.Sc. (Manc.), *The University, Manchester,* were elected ordinary members of the Society.

Ordinary Meeting, October 31st, 1911.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was given to the donors of the books upon the table.

Mr. THOMAS THORP, F.R.A.S., made a short communication in which he suggested a new method for testing the curvature of parabolic mirrors by tilting the mirror with a delicate tangent screw so that each portion of the mirror is successively brought into a horizontal position.

Miss P. C. ESDAILE, M.Sc., read a paper entitled: "**Intensive Study of the Scales of three Specimens of** *Salmo salar*."

The paper is printed in full in the *Memoirs*.

Ordinary Meeting, November 14th, 1911.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks having been given to the donors of the books upon the table; and Mr. C. L. Barnes drew attention to the 'Catalogue of Serials in the Library' now on sale.

Mr. R. F. Gwyther, M.A., communicated an abstract of a paper by Mr. LANCELOT V. MEADOWCROFT, B.A., M.Sc., entitled, "**A Geometrical Treatment of Geodesic Torsion.**"

The paper is printed in full in the *Memoirs*.

Dr. ALFRED A. MUMFORD, Medical Officer to the Governors of the Manchester Grammar School, read a paper entitled, "**Observations upon the Improvement of the Physique of Manchester Grammar School Boys during the last thirty years.**"

The paper is printed in full in the *Memoirs*.

Ordinary Meeting, November 28th, 1911.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was accorded to the donors of the books upon the table.

Mr. C. L. BARNES repeated an experiment described in *Nature* (1911), vol. 88, p. 42, whereby a blinding flash is produced by adding a drop of water to a mixture of magnesium powder and solid silver nitrate.

Dr. J. N. PRING read a paper, entitled **"The Synthesis of Hydrocarbons and their Stability at high Temperatures and Pressures,"** by himself and Mr. D. M. FAIRLIE, M.Sc.

The paper is printed in full in the *Memoirs*.

Ordinary Meeting, December 12th, 1911.

The President, Professor F. E WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was given to the donors of the books upon the table. The following were amongst the recent donations to the Society's Library:—"*Subject List of Works on Chemistry ...in the Library of the Patent Office*," New Series, ZC—ZQ. (16mo, London, 1911), presented by the Patent Office, London; "*Guide to the Exhibition of Animals, Plants, and Minerals mentioned in the Bible*" (8vo., London, 1911), "*Guide to Mr. Worthington Smith's Drawings of Field and Cultivated Mushrooms and Poisonous or Worthless Fungi often mistaken for Mushrooms*" (8vo., London, 1910), presented by the Trustees of the British Museum; "*Catalogue of a Collection of Early Printed Books in the Library of the Royal Society*," by H. M. Mayhew and R. F. Sharpe (4to., London, 1910), presented by the Royal Society of London; "*The Revolution in Finland under Prince John Obolensky*," by V. Vladimirov, translated from the Russian by V. E. Marsden, (8vo., London, 1911), presented by the Translator; and "*A Biographical Guide to the Gaskell Collection in the Moss Side Library*," by J. A. Green (12mo., Manchester, 1911), presented by the Manchester Public Libraries Committee.

The PRESIDENT referred to the death of Sir Joseph Dalton Hooker, O.M., G.C.S.I., F.R.S., on Sunday last, December 10th, and drew attention to the loss science had thereby sustained. Sir Joseph D. Hooker had been an Honorary Member of the Society since April, 1892.

Mr. T. G. B. OSBORN exhibited specimens of *Bulgaria polymorpha*, Oeder, found in the neighbourhood of Altrincham; and also showed a series of photographs of the fungus *Coprinus comatus*, illustrating the mode of the shedding of spores, and pointing out that the gradual disappearance of the pileus is simply to allow the spores to fall freely to the ground.

Mr. T. A. COWARD communicated a paper entitled:—"**The Duration of Life of the Common and Lesser Shrew, with some notes on their Habits,**" by Mr. LIONEL E. ADAMS, B.A.

"**A Note on the Little Owl,** *Carine noctua* **(Scopoli), and its Food,**" by Mr. T. A. COWARD, F.Z.S., was read by the author.

These two papers are printed in full in the *Memoirs.*

Ordinary Meeting, January 9th, 1912.

Mr. FRANCIS JONES, M.Sc., F.R.S.E., F.C.S., Vice-President, in the Chair.

A vote of thanks was passed to the donors of the books upon the table.

Dr. C. GORDON HEWITT, F.E.S., Dominion Entomologist, Ottawa, read a paper entitled **"The Control of Insect Pests in Canada."**

The author said that Canada is unsurpassed in the variety of problems which it offers the Entomologist. Some he is permitted to solve, others baffle him by reason of their magnitude. With an area of more than three and three quarter million square miles, of which one million and a quarter square miles are forest lands, and extending from a latitude of 42 degrees to the Arctic Ocean, with her shores washed by three oceans and her land rising to an elevation of over nineteen thousand feet, the variations in climate may readily be understood. The vastness of her plains will be appreciated when it is remembered that the three western or prairie provinces—Manitoba, Saskatchewan, and Alberta—are larger than France, Germany, and Italy combined, and include the finest grain-producing land in the world. At the one extreme in South-Western Ontario, grapes and peaches ripen out of doors, and a shade temperature of over 95 degrees is a common occurrence in the summer; at the other extremes good wheat can be grown at Fort Simpson, on the Mackenzie river, 800 miles north of Winnipeg, and in latitude 61·52 degrees, where the thermometer drops to 50 degrees below zero Fahrenheit in the winter. Thus, briefly, may the physical facts be summarised.

So great an area, including as it does widely different climatic and other conditions, implies a very considerable variety of insect life. In addition to variety, it involves no little difference and possibility of difference in the behaviour of the same species in different parts of the country. But the fact which to my mind is of the greatest interest is that in Canada it is possible to witness a gradual disturbance of the natural conditions by the bringing under cultivation from a previously wild and virgin state thousands of square miles every year. Insect life is quickly responsive to a disturbance of the natural balance which exists prior to the invasion of man into new territories. Insects previously existing on native wild plants when provided with large quantities of available food in the form of newly-planted crops multiply very rapidly, and assume an economic importance of a very serious nature. Further, owing to the rapid development of the country and its colonization, large quantities of vegetation, fruit, ornamental and other trees are imported in annually increasing quantities, with the possibility of the introduction of insect pests from other countries, which on being introduced may prove to be more serious in their ravages than in their native country. Instances of these phenomena will be mentioned in the following account in which I have endeavoured to describe briefly the means which are being adopted in Canada to prevent the introduction of insect pests, and to control or eradicate those pests already existing within the Dominion. It may be of interest to refer briefly to the early work which was carried on against insect pests.

HISTORY.

No work of an official nature had been carried on prior to the confederation of the provinces in 1867. The Canadian Entomological Society had encouraged the study of injurious insects since its foundation in 1863, and in 1868 it published the first number of "*The Canadian Entomologist*," which served to record the results of such studies. In the following year the Society received a grant from the Council of the Agricultural and Arts Association for the formation of a collection and the publication of a work on "Insects Useful or Prejudicial to Agriculture and Horticulture." Accordingly the "First Annual Report of the Noxious Insects of the Province of Ontario" was prepared in 1870, and published by the Provincial Government of Ontario in 1871. It included accounts of the insects affecting apple, grape, and plum, and an edition of three thousand was soon exhausted. In 1871 the Government of the Province of Ontario passed a statute incorporating the Canadian Entomological Society as the "Entomological Society of Ontario," which was instituted "for the investigation of the character and habits of insects, the improvement of entomological science and more especially its practical bearing on the agricultural and horticultural interests of the province." A grant was made to the Society by the Provincial Government, and the First Annual Report of the Entomological Society of Ontario was published. The annual publication of this report, which contains articles chiefly of an economic and practical nature, has been continued, and the Provincial Government at present makes an annual grant of one thousand dollars to the Society. No steps in a similar direction were taken by the Dominion Government until 1884, when an inquiry was held as to the desirability of appointing a Government Entomologist, and the Select Committee recommended that such an officer be appointed. Accordingly, in 1885, the Minister of Agriculture appointed a Dominion Entomologist, selecting for the position Mr. James Fletcher, who had been acting in an honorary capacity as Entomologist to the Department of Agriculture since 1884, and had issued his first report on injurious insects. When the Dominion Experimental Farms were established in 1886 this officer was attached to that branch of the Department of Agriculture in the joint capacity of Entomologist and Botanist. This position was occupied by Dr. Fletcher until his death in 1908. Owing to the increase in entomological work, and the necessity for its further extension, the old Division of Entomology and Botany was divided, and separate Divisions of Entomology and Botany were established in 1909. In that year the author was appointed as Dominion Entomologist, and entrusted with the work of organizing the new Division of Entomology.

THE INVASION OF INSECT PESTS.

Brief reference has been made to the effect which the opening up and settlement of a new country has upon the insect life of that country. Not only is the native insect life affected, but the gates of a promised land are thrown open to the alien hordes without, and the history of economic entomology in Canada is a record of successive invasions of injurious insects, or of the first discovery of their previously unnoticed entry. Most of our seriously injurious insects are species which have invaded Canada from without. The Hessian Fly (*Mayetiola destructor* Say) reached Canada about 1816. A few years later it was followed by another serious pest of Canada's staple crop, namely, the Wheat Midge (*Diplosis tritici* Kirby), which crossed the frontier in 1828, and from time to time has been responsible for enormous losses. In 1866 the Chinch Bug (*Blissus leucopterus* Say), which in sixty years has exacted a toll of not less than three hundred and fifty million dollars in the United States, was first found in Ontario. Four years later the Colorado Potato Beetle (*Leptinotarsa decemlineata* Say), in devastating millions, swept across the frontier, and now is the most commonly reported pest in Eastern Canada, and in its spread westward has reached Alberta.

All these insects confined their ravages to field and cereal crops. In 1882, however, it was discovered that the Larch Sawfly (*Lygaeonematus erichsonii* Hartig), which had been first observed five years previously in the New England States, had reached Canada. Its depredations were so serious that in a few years the mature larches, or tamaracks, over practically the whole of Eastern Canada, were almost completely destroyed. About 1887 the Dominion Entomologist received specimens of the Pear-leaf Blister Mite (*Eriophyes pyri* Nalepa) from Nova Scotia, which, although it is not an insect in the strict sense, for practical purposes is regarded as such. It was undoubtedly introduced on nursery stock from Europe, and has now spread throughout the whole breadth of Canada, from the Atlantic to the Pacific, and is increasing in abundance, and the extent of its injuries are becoming more noticeable annually. The milling industry was the next to be seriously alarmed by the sudden appearance in Ontario, in 1889, of the dreaded Mediterranean Flour Moth (*Ephestia kuhniella* Zeller). This European pest received the immediate attention of the Provincial and Federal departments of Agriculture. The Clover Root-borer (*Hylesinus trifolii* Müller), which is very destructive to clover, and is a European insect, was first recorded in Ontario in 1891.

Passing over the next three years, during which period several new insect pests were observed for the first time, we find that the next serious pest which reached Canada was the Horn Fly (*Haematobia serrata* Rob. Desv.). This insect was introduced into the United States from Europe, and was first observed in Canada in 1892, when its appearance in Ontario caused considerable alarm among farmers. Cattle which are attacked by this insect rapidly lose flesh, and the milk yield is also seriously affected. Two new pests appeared in 1896. In British Columbia the caterpillar of a small moth (*Argyresthia conjugella* Z.) was found inflicting serious injuries to apples, on which account it is named the Apple Fruit-miner. A new apple pest also appeared in Ontario owing to the fact that one of the fruit-flies, whose larva is now known as the Apple Maggot or Railroad Worm (*Rhagoletis pomonella* Walsh), ceased to confine its attention to wild fruit and haws and attacked cultivated apples, of which it is a most serious pest at the present time in certain parts of Eastern Canada. The insect which has been responsible for the greatest injury to fruit trees in certain of the regions where it became established was the San José Scale or Pernicious Scale (*Aspidiotus perniciosus* Comst.). Originally introduced into California from Asia, it spread to Canada, where it was discovered in the Okanagan Valley in British Columbia in 1894, and two years later in Ontario, where it became firmly established and destroyed acres of orchards. In 1898 the San José Scale

Act was passed, which prohibited the importation of trees, plants, and other nursery stock from countries in which the scale was present. Later, in 1901, this enactment was modified, and the aforementioned vegetation was allowed to enter Canada at certain periods of the year, and through certain ports, at which were erected fumigating houses for the fumigation of the plants with hydrocyanic acid gas. In 1899 other enemies of field and garden crops invaded our territories from the United States. The Pea Aphis (*Macrosiphum destructor* Johnson) appeared in enormous numbers in Ontario and the maritime provinces, causing considerable damage. The two Asparagus beetles (*Crioceris asparagi* L., and *C. 12-punctata* L.) crossed over from the State of New York into the Niagara peninsula. The invasion or first appearance of other injurious insects might be mentioned, but this summary of the history of insect invasions of Canada has already reached a considerable length, and the last insect to migrate into our territories from the United States will alone be considered. This insect is the Brown-tail Moth (*Euproctis chrysorhoea* L.), which appears to have been introduced into the State of Massachusetts on nursery stock from Europe about 1890, and together with the Gypsy Moth (*Porthetria dispar* L.), which was also introduced from Europe into Massachusetts, has spread over a large area in the New England States, has entailed enormous losses and the expenditure of millions of dollars in control and eradicative work. At the present time, in the State of Massachusetts alone, over a million dollars are annually being spent in endeavouring to control and prevent the spread of these two species of introduced insects. The Brown-tail Moth gradually spread in a north-easterly direction, and in 1902 specimens of the moth were taken in New Brunswick, but it was not until 1907 that evidences of the actual establishment of the insect were found in Canada. In that year thousands of the winter webs in which the young caterpillars pass the winter were found in Nova Scotia, and the further discovery of the insect in 1910 in New Brunswick indicated that it had firmly established itself in Canada.

FEDERAL LEGISLATION IN CANADA AGAINST INSECT PESTS.

A brief reference has already been made to the San José Scale Act, which was passed by the Federal Government in 1898, prohibiting the importation of trees and other nursery stock from countries in which the San José Scale occurred. In 1901, fumigation stations were established at six of the Customs ports, through which nursery stock was allowed to enter during certain periods of the year after fumigation with hydrocyanic acid gas. Beyond this power to fumigate imports, the Federal Government had no authority to take further action, should it be necessary, to prevent the introduction of further insect pests into Canada or the spreading of insect pests in Canada. In 1909, winter webs of the Brown-tail Moth were found on shipments of nursery stock imported from France into Ontario, Quebec, and British Columbia: the same insect was also firmly established in Nova Scotia. It was necessary, therefore, that we should have the necessary powers to prevent the introduction of this pest into those parts of Canada not already infested and its spreading in regions where it had become established. Accordingly, the Destructive Insect and Pest Act was passed in 1910, under which regulations were made providing for the prohibition of entry, fumigation on entry, or inspection subsequent to entry, of nursery stock, or defining other conditions under which nursery stock and other vegetation might be introduced into Canada. The regulations, which include all the provisions of the San José Scale Act, also provided for the treatment of vegetation or premises to prevent the spreading of insect pests, the destruction of any crop, tree, and other vegetation infested, or suspected to be infested, the granting of compensation, and such other steps as might be considered necessary to carry out the objects of the Act.

All vegetation and nursery stock, except certain classes of florists' stock, such as green-house grown plants, herbaceous perennials, bedding plants, etc., is allowed to enter Canada through certain ports only, at six of which, namely, St. John, N.B.; St. John's, P.Q.; Niagara Falls, Ont.; Windsor, Ont.; Winnipeg, Man.; and Vancouver. B.C., fumigation stations are established, where stock requiring fumigation is fumigated before being released by the Customs, and a certificate of fumigation is given. For stock requiring inspection, a different procedure is necessary. All vegetation and nursery stock, except the classes already mentioned, coming from Europe, Japan, or the States of Vermont, Maine, Massachusetts, New Hampshire, Connecticut, and Rhode Island, is inspected, and the general method of procedure is as follows:—

Any person importing nursery stock is required to send to the Dominion Entomologist, within five days of ordering this stock, a notice of his order, which must give the name of the consignee, place of origin, the quantity and nature of the stock. When the shipment arrives, a notice of its arrival is sent by the Customs officers to the Dominion Entomologist, and the importer and Custom House brokers are also required by the regulations to send a notice of its arrival. Two methods may then be followed: Nursery stock entering through certain ports, such as Vancouver or Winnipeg, is inspected at the port of entry, and after it bears a certificate of inspection it is allowed to proceed to its destination. Nursery stock entering Ontario through certain ports, however, is allowed to proceed to its destination, and on notices of its arrival being received from the Customs officers and the importer, an inspector is immediately instructed to visit the consignee for the purpose of inspecting the stock. Under the regulations, the consignee may not unpack the stock, except in the presence of an inspector, who, after inspecting the same, issues a certificate of inspection.

The species of insects which are scheduled under the Destructive Insect and Pest Act are San José Scale, *Aspidiotus perniciosus*; Brown-tail Moth, *Euproctis chrysorrhœa*; Woolly Aphis, *Schizoneura lanigera*; West Indian Peach Scale, *Aulacaspis pentagona*; Gipsy Moth, *Porthetria dispar*. Other insects may be scheduled should it be deemed necessary at any time. Over two and one-half million plants were examined in Eastern Canada during the importation season 1909-1910, and over three hundred of the winter webs of the Brown-tail Moth were discovered on nursery stock from France. These nests of the Brown-tail Moth may contain several hundreds of the young hibernating caterpillars of this insect. During the last importation season over four million trees and plants were inspected. Recently, pupæ of the Gipsy Moth, fortunately dead, were found on Azaleas imported from Belgium. These facts indicate the importance of inspection of imported trees and plants collectively classed as nursery stock. In the work of inspection the Provincial Departments of Agriculture concerned co-operate with the Federal Department. In Ontario assistance is rendered in the inspection of shipments of nursery stock. British Columbia, as will be mentioned later, has regulations governing the inspection of imported nursery stock and also fruit, and as the Federal and Provincial inspection and fumigation work is carried on at Vancouver the two departments co-operate to avoid, as far as possible, unnecessary duplication of the work.

PROVINCIAL LEGISLATION AGAINST INSECT PESTS.

In addition to the legislation of the Dominion Government against insect pests, several of the Provincial Governments have enacted legislative measures relating to the prevention, control, and eradication of insect pests in their respective provinces. In 1892, the Province of British Columbia passed a Horticultural Board Act, creating a Board with power to pass regulations for the purpose of preventing the introduction or spread of injurious insects, under which are included :—Woolly Aphis, Apple-tree Aphis, Scaly (scurfy?) Bark Louse, Red Scale, Borers, Codling Moth, Currant Worms, Caterpillars, and other known injurious insects.

As is evident, this wide definition of insect pests gives the Board the greatest latitude in eradicating and preventing the introduction of injurious insects. A careful inspection is made of all nursery stock and fruit entering the province, and until such inspection has taken place the importations are in quarantine. Shipments may also be fumigated if it is considered necessary. The regulations are administered by the Provincial Inspector of Fruit Pests, who is assisted by a staff of inspectors. These inspectors conduct the inspection and fumigation at Vancouver and eradicative measures in the nurseries and orchards throughout the Province. The large amount of nursery stock and fruit which is condemned annually, and either sent back or destroyed, testifies as to the assiduity and zeal with which the work of preventing the introduction of insect pests into the Province is carried on.

The Province of Ontario has a Fruit Pests Act, which is administered by the Fruit Branch of the Department of Agriculture. The insects which are scheduled under this Act are :—San José Scale, Codling Moth, and Pear Psylla. The work is carried on chiefly in conjunction with the municipalities, which appoint inspectors in addition to those appointed by the Provincial Department of Agriculture. These inspectors have power to order the treatment or destruction of infested trees and plants. Owners of nurseries are compelled to fumigate stock before it leaves the nurseries, and inspectors visit the nurseries for the purpose of destroying infested trees, and seeing that the fumigation regulations are carried out.

The Province of Nova Scotia has recently (1911) passed an Injurious Insect Pest and Plant Disease Act, which enables the provincial authorities to appoint inspectors and to take steps to eradicate insect pests and to prevent their spread. It is intended to introduce a measure shortly providing for the compulsory spraying in such districts as may desire it. This measure will be most valuable, if carried out, in compelling indifferent persons to adopt necessary measures of control.

THE BROWN-TAIL MOTH.

The invasion of the Brown-tail Moth has already been mentioned, and an active campaign is now being carried on with a view to controlling the Brown-tail Moth in those counties of Nova Scotia and New Brunswick in which it has established itself. This work chiefly consists in scouting the countryside for the winter webs of the caterpillars, and the destruction of these where found. Some of these webs contain enormous numbers of caterpillars; a single web or nest collected in Nova Scotia was found to contain over 1800 caterpillars, which indicates the importance of destroying even single webs. The insects occur mostly upon the fruit trees, but also on the wild varieties of apple, rose, and thorn, and on hardwoods such as oak, elm, maple, &c. In places where winter webs are found in considerable abundance, the trees are thoroughly sprayed after the appearance of the foliage. When the pest first arrived in Canada it was believed by many that the winters would be too severe for the young hibernating caterpillars. Experience has shown that this is not so, and experiments have proved that winter webs containing live larvæ will stand being frozen in a solid block of ice for nearly two months, after which about thirty per cent. of the larvæ are still alive. The parasitic enemies of the insect are being studied, and the Division of Entomology will attempt to use these means in endeavouring to obtain a natural control of the pest. In the work of scouting for and destroying the winter webs, the Federal Department is assisted by the Provincial Department of Agriculture.

THE DIVISION OF ENTOMOLOGY.

In addition to the work of inspecting and fumigating trees and plants imported into Canada carried on under the Destructive Insect and Pest Act, and the Brown-tail Moth control work, which activities have already been described briefly, the Division of Entomology also carries on many other lines of work. The problems of insect control are intimately related to agriculture, horticulture which includes fruit-growing, forestry, public health and other activities of man; in proportion as these activities increase in importance, the knowledge of the means of insect control likewise increases. On farm crops in Canada insects levy an annual toll at the present time of at least fifty million dollars, and a very conservative estimate would indicate that the fruit-growers of Canada experience an annual loss of over four million dollars owing to insect pests. These figures may appear rather large to the uninitiated, but it should be remembered that a loss of thirty per cent. in fruit-growing, and a loss of ten to twenty-five per cent. in the raising of farm crops, is generally assigned to injurious insects. Further, it is safe to say that even with our present knowledge of the methods of insect control, a saving of at least thirty per cent. could be effected, and with increased knowledge this percentage will undoubtedly increase. One of the chief objects of the work of the Division of Entomology is to assist farmers and fruit-growers in the prevention of these losses. All should realize that it is a poor policy to advocate methods for the purpose of increasing the productivity of the soil if, at the same time, steps are not taken to lessen the means responsible for reducing, in so large a measure, the crops so produced.

Enquiries and reports concerning insect injuries are received from all parts of Canada. All correspondence to and from the Division is carried "Free," no postage being required, thereby enabling all who desire to have information to obtain it free of cost.

By co-operation with other branches of the Department of Agriculture the Division is able to increase its usefulness. The Census and Statistics Branch has a body of correspondents of about six thousand, who report to that Branch each month on the conditions of the crops in the different provinces. A question is also asked with reference to insect pests, and the replies are referred to the Division. In this way it is possible immediately to communicate with such correspondents as may need assistance, or if the pest is of a serious nature, to issue a statement to the local press of that district. Such an arrangement is also valuable as a means of receiving information of the incipient stage of an outbreak of an injurious insect. The Fruit Branch has similar correspondents reporting the conditions in regard to the fruit crops, and they also are asked concerning insect injuries. By these means the Division is in communication with practically every section of the Dominion, and is kept well infromed as to the occurrence of injurious insects affecting farm and fruit crops.

With so vast an area it is necessary to study the insects and the methods of control in the regions where they occur; the life history of an insect in Quebec will probably differ from its life history in British Columbia, and the methods of control must be adopted according to such differences. Field Stations are being established in different regions in Nova Scotia, New Brunswick, Quebec, Ontario and British Columbia for the study of fruit insects, and it is hoped to establish one in the western provinces for the study of insects injurious to cereals.

One of Canada's most valuable reserves are the forests. The forest area is estimated at about one and a quarter million square miles, of which about four hundred thousand square miles are covered with merchantable timber. In 1910 over three and a half million dollars' worth of pulpwood were produced. As injurious insects form one of the chief forest-destroying agencies, the important relationship which forest entomology bears to the question of the conservation of the forests needs no emphasis. This study of forest insects has not received in the past the attention its importance warrants, but an Assistant Entomologist, who is a recognised authority on the bark beetles—the most destructive of forest insects—has been appointed with the intention of developing this branch of entomological work. The officers and forest rangers of the Forestry Branch of the Department of the Interior are co-operating in the work by making field observations and reports on forest insects.

A large number of enquiries are received concerning apiculture, and an apiary is kept for experimental purposes. Increasing attention is being devoted to bee-keeping throughout Canada, and with the development of the fruit-growing industry, there should most certainly be a concomitant development in apiculture. The most serious impediment to its development is the spread of the disease known as European and American Foul Brood. Both these diseases have been introduced into Canada, and the Provinces of Ontario, Quebec, and British Columbia have enacted statutes with a view to preventing their spread.

Insects and ticks affecting live stock are a serious problem in many parts of Canada. The well-known Warble Fly (*Hypoderma lineata* Villers) is so prevalent in certain regions, that as much as two dollars per head is frequently deducted from the price paid for young stock on account of the injuries of these insects. Through the co-operation of the Veterinary Director-General of the Department of Agriculture, reports and specimens are received from the veterinary inspectors throughout the Dominion, and a knowledge is being gained of the prevalence and distribution of these insect enemies of live stock.

In British Columbia, a few years ago, many complaints were made by fruit-growers concerning the condition of the orchards on the Indian Reservations, which in many sections adjoin or are situated in fruit-growing sections. The Indians, partly through ignorance and largely through indifference, paid little attention to the orchards in their Reservations, with the result that insect pests of all kinds, being unmolested, flourished in abundance. The result was that the Indian orchards served as breeding-grounds and sources of supply for insect pests. Through strong representations being made to the Department of Indian Affairs, an annual appropriation is made by that Department "for the cleansing of Indian orchards," and this work is administered by the Dominion Entomologist. An officer is employed who devotes his whole time to this work. The Indian Reservations are visited, and the Indians are instructed in the methods of spraying, pruning, and generally cultivating their orchards. This work has already had very beneficial results, and many of the Indians are possessors of good orchards and produce excellent fruit, and the orchards in the Reservations are becoming less menacing to the orchards of the neighbouring fruit-growers. A vigorous educational campaign is carried on in reference to the relation of insects to man. By lectures illustrated by lantern slides and cinematograph, by circulars freely distributed, and by articles in the press, the public is being impressed with the necessity of abolishing the house fly as a means to sanitary reform and the reduction of the death rate, especially among infants, due to intestinal disease, such as typhoid, in the carriage of which flies play so large a part in Canada.

So far, mention has been made chiefly of the strictly practical aspects of the work of the Division of Entomology. Considerable time is occupied, however, in educational work. Agricultural and fruit-growers' associations, and meetings in the different provinces, are addressed on injurious insects and means of control. An increasingly large and representative collection of Canadian insects, which it is intended shall form the basis of a national collection, is maintained, and is largely used in determining collections of insects sent in by individuals, schools, and colleges for identification. Although such work involves much time and labour, its educational value is undoubtedly great apart from benefits which may accrue to the Division.

This account of the work of the Division of Entomology is necessarily brief, but it may indicate the great variety of problems with which we have to deal, and the many interests which are affected by injurious insects to which interest our work is accordingly related. As the development and growth of Canada is wholly dependent upon agriculture, the basic principle of the country's prosperity, the importance of the work thus briefly described, and its necessary increase, will be readily understood.

OTHER WORK ASSISTING IN THE CONTROL OF INSECT PESTS

In addition to the work carried on by the Federal Government, much valuable work is effected by several of the Provincial

Departments of Agriculture. Reference has already been made to the work carried on by the Provinces of British Columbia and Ontario under their respective statutes.

The Province of Ontario has always been in the forefront in Canada in regard to taking steps for the control of insect pests. This is due, to no small extent, to the fact that there exists in the Ontario Agricultural College at Guelph, which is maintained by the Provincial Government, an excellent Entomological Department, in which men are trained in this work, and are available for employment either by the Provincial or by the Dominion Departments of Agriculture. The Entomological Department of the College also serves as a bureau of information in the control of insect pests for the province, and the members of the staff carry on an active educational campaign. The Province of Nova Scotia carries on similar work, though to a less degree, in that Province. The Macdonald Agricultural College in Quebec, though a branch of McGill University, and supported by the endowment of its founder, carries on entomological work in the Province of Quebec; it is not supported, however, by the Provincial Government.

From this account of the problem of the control of insect pests in Canada, and the methods by which it is being attacked, some idea will be gained of its magnitude and the many interests with which it is concerned. The dependence of agriculture and forestry, to name Canada's greatest national assets, on scientific investigation, is becoming increasingly an acknowledged fact, and the people of Canada are recognising the fact, pointed out by the Right Hon. Earl Grey in opening the first meeting of the Conservation Commission of Canada, "that the future prosperity of Canada depends upon scientific research and upon the efficient application of the results of that research to the industrial and physical lives of the people."

General Meeting, January 23rd, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

Mr. CHARLES ERNEST WOLFF, M.Sc. (Manc.), Assoc. M.Inst.C.E., Consulting Engineer, of *The Clough, Hale, Cheshire*, was elected an ordinary member of the Society.

Ordinary Meeting, January 23rd, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was passed to the donors of the books upon the table. The following were amongst the recent accessions to the Society's Library: "*Les Prix Nobel en 1909*" (8vo., Stockholm, 1910), "*Les Prix Nobel en 1910*" (8vo., Stockholm, 1911), "*Meridiangradmätning vid Sveriges Västra Kust*," by P. G. Rosén (4to., Uppsala and Stockholm, 1911), presented by the Académie Royale Suédoise des Sciences, Stockholm; "*Subject List of Works on Chemical Technology ... in the Library of the Patent Office*," New Series, YN-ZB (16mo, London, 1911), "*Subject List of Works on Peat ... in the Library of the Patent Office*," New Series, YK-YM (16mo., London, 1911), presented by the Patent Office, London; "*Report on William Penn Memorial in London*, ... MCMXI," by Barr Ferree (8vo., New York, 1911), presented by the Pennsylvania Society, New York; "*Flora Capensis*," vol. 5, sect. I., part 3, by Sir W. T. Thiselton-Dyer (8vo., London, 1911), purchased; "*A Bibliography of Wisconsin's Participation in the War between the States*," by I. S. Bradley (8vo., n.p., 1911), presented by the Wisconsin History Commission; "*Evolution of Mammalian Molar Teeth*," by H. F. Osborn

(8vo., New York, 1907), and a collection of some eighty reprints, from various journals, of papers by H. F. Osborn, presented by the author.

Mr. T. THORP, F.R.A.S., in presenting a crossed transparent grating to the Society, pointed out that the secondary spectra produced by the crossing of the gratings are quite pure and free from all "scatter."

A hearty vote of thanks was given to Mr. Thorp for his valuable present.

Mr. J. R. GWYTHER, M.A., read a paper entitled, "**On the modes of rupture of an open hemispherical concrete shell under axial pressure.**"

The paper is printed in full in the *Memoirs*.

A note on the mechanical conditions involved in the above question was read by Mr. R. F. GWYTHER, M.A.

General Meeting, February 6th, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

Mr. H. G. FORDER, B.A., Mathematical Master, Hulme Grammar School, Oldham, was elected an ordinary member of the Society.

Ordinary Meeting, February 6th, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

Mr. H. E. SCHMITZ, M.A., B.Sc., and Mr. G. P. VARLEY, M.Sc., were nominated auditors of the Society's accounts for the session 1911-1912.

A vote of thanks was given to the donors of the books upon the table.

Mr. T. A. COWARD, F.Z.S, exhibited a living specimen of a Wall Gecko, *Tarentola mauritanica*, captured at Broadheath, Altrincham, on January 22nd last, and made a few remarks regarding its food and habits.

MR. WILLIAM BURTON, M.A., F.C.S., read a "**Note on the earliest Industrial use of Platinum.**"

He stated that his investigations into the history of the potter's craft have, from time to time, thrown interesting side-lights on the development of other arts and sciences. Some years ago he was struck by the appearance of platinum as an adjunct to English pottery at a period when the metal was only a chemical curiosity. Unfortunately he was unable to give the dates with the precision he would like, because the early records of such eminent firms as Josiah Wedgwood & Sons and Johnson, Matthey & Co. have been lost or destroyed; but he had been able to establish certain data which were of sufficient general interest to warrant his bringing this note before the Society, where it might provoke discussion and further elucidation.

The general history of the introduction of platinum from South America into Europe, and its recognition as a noble metal, is carefully abstracted in many works, notably in the latest edition of Roscoe & Schorlemmer, so that it need not be detailed. Small supplies of native platinum reached Europe between 1740 and 1770. The first scientific account of it was given by William Watson in the *Phil. Trans.* of 1750, but it was not until 1784 that Achard prepared the first rudimentary platinum crucible, and both the foil and wire were scientific curiosities. Even as late as 1801 it is stated that the eminent chemists Gustav Rose and Karsten were unable to procure a platinum crucible. The first development of the metallurgy of platinum originated in England—at the hands of the firm of Johnson, Matthey & Co.—but this was only in the period 1800-1808.

It is interesting to note that one reason for the scarcity of platinum in Europe during the latter half of the 18th century is stated to have been the action of the Spanish Government in decreeing that platinum should be thrown into the sea as its only known use was to adulterate gold coinage. In 1788, however, the Spanish Government, presumably to depreciate the gold coinage on its own account, suspended this edict and began to buy platinum in South America at the rate of 8/- per lb., and within twenty years the manufacture of platinum wire, foil and apparatus was established in England.

English pottery decorated with platinum was, however, an article of extensive manufacture from 1790 or thereabouts, so that, I believe, this must take precedence over the other industrial applications of the metal. Why this particular application of the metal should appear so early appears to be quite simple. The principal potters of that day in England, France and Germany were connected with the various learned societies, and the properties of this curious new substance, so refractory and so resistant to solution in acids, attracted widespread attention. Solutions of gold in aqua regia had been used for some time as a means of producing thin films of gold on pottery; the earliest examples I have ever seen were prepared by Böttger, the Alchemist, who first made true porcelain in Europe, and he died in 1719. It seems natural, therefore, that a potter like Josiah Wedgwood, who associated with the best scientific men of the day and was an active member of the Royal Society, should turn his attention to platinum. From Wedgwood's correspondence it is clear that as early as 1775 he had been in communication with Dr. Fothergill and others as to the production of metallic deposits on pottery, and the only patent he ever took out was connected with this subject. We also know that between 1780 and 1790 he was endeavouring to produce his famous black ware with a surface of metallic silver. Sometime in 1790-91 he, or his youngest son Thomas Wedgwood (the man who produced the first sun-prints on paper sensitised with a silver salt), finally produced the so-called English silver-lustre pottery, which is pottery coated with a shining surface of platinum.

The method by which this surface was obtained is exceedingly simple. A solution of platinum in aqua regia was slowly poured, with careful stirring, into about three times its bulk of an oily menstruum, such as balsam of sulphur or spirits of tar. This forms an oily pigment which can be applied to a piece of glazed pottery so as to obtain a uniform coating. When the oily coating has become tacky by drying, a film of finely divided platinum, obtained by charring ammonium-platino-chloride, is dusted upon it, and when the ware is again fired at a low heat, say 700°-800° C., a brilliant metallic deposit of platinum is found fixed to the glaze.

This pottery has always been known as silver-lustre, though it has no more right to the name "lustre" than to that of "silver." The term "lustre" as applied to any pottery decoration should be definitely restricted to those films of silver, copper or gold which are so thin as to exhibit interference colours like a soap-bubble does. Some years ago I suggested for this form of English pottery the term "plated ware," as it was so obviously intended to be a cheap substitute for the silver plate of the period. The shapes of the articles manufactured were mostly copied from the popular Sheffield plate of the day, and the new pottery was so successful that by about 1800 the process was being followed at ten or a dozen factories in the Staffordshire potteries, as well as at the famous potteries at Leeds and elsewhere. Gradually it lost its popularity, and by about 1850 had almost fallen into disuse; but within the last few years the method has been revived, and is now extensively employed both by English and Continental firms for pottery decoration.

Professor ERNEST RUTHERFORD, D.Sc., F.R.S., read a paper on "**The origin of the β rays from radio-active substances.**" He said that from a study of radio-active transformations it has been found that each atom of matter in disintegrating emits one α particle expelled with a definite velocity, which is characteristic of the substance. In many transformations, β and γ rays are emitted, and from analogy it would be expected that one β particle should be emitted for the transformation of each atom. The experiments, however, of Baeyer, Hahn and Miss Meitner, and of Danysz, have shown that the emission of β rays from the radio-active substances is, in most cases, a very complicated phenomenon. The complexity of the radiation is most simply shown by observing in a vacuum the deflexion of a narrow pencil of β rays by a magnetic field. If the rays fall normally on a photographic plate, a number of sharply marked bands are observed, indicating that the rays are complex and consist of a number of homogeneous sets of rays each of which is characterised by a definite velocity. The remarkable complexity of the β radiation is well instanced by the experiments of Danysz, who found that the products of radium B and C together emitted at least 27 sets of homogeneous rays. Some of these had a velocity exceedingly close to that of light. Notwithstanding this apparent complexity, general experiments have shown that the number of β particles emitted from radium B and C is about that to be expected if each atom in breaking up emits only one β particle. In order to explain this complexity of the β rays, it is necessary to suppose either that the atom breaks up in a number of distinct ways, each of which is characterised by the emission of rays of definite velocity, or that the energy of the β particle can be reduced by certain definite amounts in its escape from the radio-active atom. The latter view appears more probable and more in accordance with the facts observed. It was found from an analysis of the results given by Danysz that certain relations existed between the energies of the individual β particles composing some of the different sets of rays. The difference in the energies of the β particles from radium B and from radium C could be expressed by a relation of the form $pa + qb$, where a and b were definite constants and p and q had integral values 0, 1, 2, 3, &c.

This result may be explained by supposing that the β particle initially is liberated within the atom endowed with a certain speed, but that in escaping from the atom it may pass through two or more regions in which the quantity of energy a or b is abstracted. The number of these units of energy abstracted will vary from atom to atom, each individual atom probably giving rise to only a few of the types of β rays observed. Evidence was given that the values a and b served as a measure of the energy of the γ rays emitted from radium, and were connected with the energy of the β particle required to excite the characteristic radiations in the atoms of radium B or C.

It is of great theoretical importance to examine with the greatest care the nature of the emission of β rays from all the known radio-active substances, for it promises to throw a great deal of light on the interior structure of the atom.

Ordinary Meeting, February 20th, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was given to the donors of the books upon the table, which included "*The Medical Chronicle*," vol. iv. (1886)—vi. (1887); New Series, vol. i. (1894)—x. (1899); 3rd Series, vol. i. (1899)—iv. (1901); 4th Series, vol. i. (1901)—xxii. (No. 3, Dec., 1911), (8vo., Manchester and London); presented by Dr. A. A. Mumford. Mr. Barnes also drew attention to a few bound sets of Dr. A. N. Meldrum's seven papers on "*The Development of the Atomic Theory*," which are now offered to members at 2/- per volume.

Mr. T. G. B. OSBORN, M.Sc., gave a brief account of recent investigations into the nature of the moulds which attacked exported cotton goods. Several common fungi and bacteria were found infecting the goods.

Professor W. H. LANG, M.B., D.Sc., F.R.S., read a paper entitled, "**Branching in the Ophioglossaceae.**"

The branching in Ophioglossaceae is of special interest for comparison with that known for the Zygopterideae and Hymenophyllacae. Branches occur occasionally in all three genera of the Ophioglossaceae. So far as is known those of *Ophioglossum* always spring from lateral roots. In *Helminthostachys*, what appear to be dormant or vestigial axillary buds, were discovered by Gwynne Vaughan, and are constantly found. Similar dormant buds were found by Bruchmann in young plants of *Botrychium lunaria*, and explain the axillary branching described by Roeper and Holle.

Examination of young and old plants of *Botrychium lunaria* has shown that a dormant bud is constantly present in each leaf-axil. In some cases a vestigial vascular supply, in the form of two slender and evanescent strands of tracheides, springs from the margins of the subtending leaf trace. Two examples in which, owing to destruction of the apex of the main axis, a lateral branch had developed, were studied in detail, and the vascular supply to the branch traced from the adaxial side of the leaf-trace. In one case the stele of the branch became continuous at a higher level and for a short distance with the stele of the main axis.

Two fragments of the rhizome of *Helminthostachys*, each bearing a developed axillary branch, were studied in detail. This examination completely confirmed the interpretation of the structures found by Gwynne Vaughan as vestigial buds. The supply to the branch came from a development of accessory xylem outside the ordinary xylem of the stele of the rhizome, and not from the leaf-trace. This vascular supply is traceable from about the level of the departure of the subtending leaf-trace to the anterior end of the leaf-gap, where the vestigial bud is normally situated. From here onwards it has assumed the structure of a small stele like that found in young plants, and shortly afterwards the branch exhibits its own proper cortex.

The relations of the axillary bud are here with the stem and not with the subtending leaf-trace. The accessory xylem may all pass off to the branch or may be more extensive, occurring all round the main stele, and persisting after the departure of the branch. In the latter case its development suggests a comparison with secondary thickening.

Thus the branches which occur occasionally in *Botrychium* and *Helminthostachys* are not "adventitious," but derived from axillary buds that are constantly present. While not agreeing in detail with the branches in the Zygopterideae, those of the Ophioglossaceae are clearly comparable structures, and the study of their vascular supply strengthens the probability of a relationship between the two groups.

Ordinary Meeting, March 5th, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

The PRESIDENT referred to the loss the Society had sustained by the death, on February 21st, of Professor Osborne Reynolds, LL.D., F.R.S. Professor Osborne Reynolds had for many years taken a most active part in the work of the Society. Elected as a Member on November 16th, 1869, he was for many years a Secretary or Vice-President; and, in 1888 and 1889, was elected President of the Society. Professor Reynolds had contributed many important Papers to the Society's *Memoirs.* Mr. Francis Nicholson proposed, and Mr. Francis Jones seconded, that the President be requested to send to Mrs. Reynolds on behalf of the Society a letter of condolence on the death of her husband. This proposition was unanimously agreed to.

A vote of thanks was passed to the donors of the books upon the table. These included a copy of "*Literary Celebrities* *of the English Lake-District*," by Frederick Sessions, (8vo., London, 1907), presented by the author.

Mr. J. H. WOLFENDEN exhibited a specimen of hæmatitic slate found near Keswick, which exhibited "cone in cone" structure such as is commonly found in the crushed carboniferous shales of Lancashire.

Mr. R. L. TAYLOR, F.C.S., F.I.C., read a paper, by himself and Mr. CLIFFORD BOSTOCK, M.Sc.Tech., entitled, **"The Action of Dilute Acids on Bleaching Powder."** In these investigations a method originally described by Taylor was used for distinguishing between free chlorine and hypochlorous acid, and, in a mixture of the two, determining their relative amounts.

Bleaching powder was distilled with varying amounts of different acids, together with a considerable amount of water. Hydrochloric, sulphuric, and nitric acids act pretty much alike, giving off, with comparatively small amounts of acid, almost pure hypochlorous acid, but, with larger amounts of acid, mixtures of hypochlorous acid and chlorine, and finally nothing but chlorine. Acetic and phosphoric acids act in the same way with small amounts of acid, but the hypochlorous acid never entirely disappears, even with large quantities of acid. When bleaching powder is distilled with boric acid (and a sufficient amount of water) practically pure hypochlorous acid is produced even when the boric acid is used in comparatively large quantities. Although at the ordinary temperature carbon dioxide liberates nothing but chlorine from bleaching powder, as the temperature is raised hypochlorous acid begins to be evolved, mixed with chlorine, and when the liquid is actively boiling practically pure hypochlorous acid is produced.

Dr. ALFRED HOLT gave an account, entitled "**Sorption of Hydrogen by Palladium,**" of researches carried out by himself, Dr. EDGAR, and Mr. FIRTH with palladium. He said that their experiments on the subject lead to the following conclusions :—

(1) Palladium is not always in a condition in which it will absorb hydrogen, but it can be made to do so by heating to about 400° C. in either air or in vacuo. The power of picking up gas dies away with time, and cannot be restored unless the metal is reheated.

(2) Hydrogen is first condensed on the surface of the metal (adsorbed layer) and then gradually diffuses inwards (absorption). It is possible to get the metal either saturated outside and with no gas in the interior, or saturated in the interior and not on the surface.

(3) Diffusion of hydrogen through the metal begins at about 120° C. and increases in rate with rise of temperature. The same temperature does not, however, always produce the same rate, as it depends somewhat on the state of the metal. The rate does not obey any simple law of diffusion or effusion.

Ordinary Meeting, March 19th, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was given to the donors of the books upon the table. The recent accessions included: "*The British Tunicata*," vol. iii, by J. Alder and A. Hancock, edited by J. Hopkinson (8vo., London, 1912), and "*A Monograph oj the British Desmidiaceae*," vol. iv, by W. West and G. S. West (8vo., London, 1912), purchased from the Ray Society.

Professor S. J. HICKSON, F.R.S., exhibited a specimen of a recent coral, *Endopachys grayi*, from the Persian Gulf, and in the course of his remarks upon it pointed out that the Manchester Museum possessed until quite recently three out of the four known specimens of this species. One of these, however, had been presented to the British Museum of Natural History. One of the specimens was reported as having been found in the China Sea, and was presented to the Manchester Museum by the late Mr. R. D. Darbishire.

Mr. C. E. STROMEYER, M.Inst. C.E., exhibited, and made a few remarks upon, a piece of tramway rail, showing the ridges and hollows due to the action of the wheels.

A paper entitled, "**The formal specification of the elements of Stress in cartesian, and in cylindrical and spherical polar coordinates,**" was read by Mr. R. F. GWYTHER, M.A.

This paper is printed in full in the *Memoirs.*

Dr. HICKLING read a paper on the "**Variation of Planorbis multiformis.**" It was shown that the shell exhibited every gradation from a perfectly flat type to one with a high spire. The mean type is represented by a large number of specimens, while the extreme types are scarce. The curve representing the relative numbers of the various types is a typical simple variation curve, thus proving that all the forms belong to a single species. Great variation occurs in other characters of the shells, and these variations appear to be independent of one another.

Extraordinary General Meeting, April 2nd, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

At this Extraordinary General Meeting, summoned in accordance with the Articles of Association, the following resolution of the Council was submitted :—

That Clause 25 of the Articles of Association be rescinded, and that in lieu thereof the following be one of the Clauses of the said Articles :—

> "25. Any ordinary member may at any time com-"pound for all his future subscriptions by a payment to "the Society of twenty guineas less one-third of the "amount of the annual subscriptions already paid, but the "fee shall in no case be less than five guineas."

After some discussion it was resolved to refer the resolution back to the Council for further consideration.

Ordinary Meeting, April 2nd, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was passed to the donors of the books upon the table.

Mr. FRANCIS NICHOLSON, F.Z.S., presented to the Society the letter, dated "2nd mo. 20th, 1794," and written by John Dalton to Elihu Robinson, of Eaglesfield, the contents of which he had previously communicated to the Society on October 17th, 1911. Mr. Nicholson had had the letter bound, with a number of additional pages, so that further letters or manuscript could be inserted in the same volume if desired.

A paper by Mr. JOSEPH MANGAN, M.A., entitled, **"The presence of Maxillulæ in Larvæ of Dytiscidæ,"** was read by the Secretary.

Professor W. H. LANG, M.B., D.Sc., F.R.S., read a paper **"On the Interpretation of the Vascular Anatomy of the Ophioglossaceæ."**

These two papers are printed in full in the *Memoirs*.

Annual General Meeting, April 23rd, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., 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*."

Mr. ARTHUR ADAMSON, A.R.C.S., and Mr. F. H. CREWE 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: F. E. WEISS, D.Sc., F.L.S.

Vice-Presidents: FRANCIS JONES, M.Sc., F.R.S.E., F.C.S.; ERNEST RUTHERFORD, M.A., D.Sc., F.R.S.; ARTHUR SCHUSTER, Sc.D., Ph.D., F.R.S.; WILLIAM BURTON, M.A., F.C.S.

Secretaries: R. L. TAYLOR, F.C.S., F.I.C.; GEORGE HICKLING, D.Sc.

Treasurer: W. HENRY TODD.

Librarian: C. L. BARNES, M.A.

Other Members of the Council: SYDNEY J. HICKSON, M.A., D.Sc., F.R.S. ; T. A. COWARD, F.Z.S. ; FRANCIS NICHOLSON, F.Z.S.; G. ELLIOT SMITH, M.A., M.D., F.R.S. ; W. W. HALDANE GEE, B.Sc., M.Sc. Tech., A.M.I.E.E. ; BERTRAM PRENTICE, Ph.D., D.Sc.

Ordinary Meeting, April 23rd, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was accorded the donors of the books upon the table. These volumes included Vols. VI.—XIV. (Second Series) and Vol. I. (Third Series) of the Society's *Memoirs*, from the library of the late Robert Barbour, for many years a member of the Society, kindly presented by his son, Mr. George Barbour.

The PRESIDENT drew attention to the death of Professor J. Dixon Mann, M.D., F.R.C.P. (Lond.), on April 6th, 1912, and to the loss the Society sustained thereby. Professor Dixon Mann had been a member of the Society since January 26th, 1875.

Mr. R. L. TAYLOR, F.C.S., F.I.C., read a paper entitled **"The Action of Bleaching Agents on the Colouring Matter of Linen."** The author showed that the colouring matter of unbleached linen is quite abnormal with regard to the action of the ordinary bleaching agents upon it, and differs from every other colouring matter with which he is acquainted. Whereas colouring matters such as indigo, Turkey-red, and the colouring matter of cotton are bleached much more rapidly by free chlorine or hypochlorous acid than by a hypochlorite, with the colouring matter of linen the exact opposite is the case, this being bleached more rapidly by a solution of a hypochlorite. Apparently the maximum bleaching effect on unbleached linen is produced by a solution of a hypochlorite which contains no free alkali, but rather some free chlorine or hypochlorous acid. Excess of alkali retards the bleaching action, just as it does in the case of other colouring matters. The addition of a chloride to the solution sometimes accelerates and sometimes retards the bleaching action (this depending upon the amount of alkali in the solution), instead of, as is the case with other colouring matters, always accelerating it.

General Meeting, May 7th, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

Mr. KURT LOEWENFELD, Ph.D., *Fern Bank, Ogden Road, Bramhall, Cheshire*, was elected an ordinary member of the Society.

Ordinary Meeting, May 7th, 1912.

The President, Professor F. E. WEISS, D.Sc., F.L.S., in the Chair.

A vote of thanks was passed to the donors of the books upon the table. These included: "*Memorie della Reale Accademia di Archeologia, Lettere e Belle Arti*," vol. I. (fol., Napoli, 1911), presented by the Società Reale di Napoli; and "*Arxius de l'Institut de Ciencies*," Any. I., no. 1 (fol., Barcelona, n.d.), presented by the Institut d'Estudis Catalans, Barcelona.

The PRESIDENT made a few remarks upon a specimen of a Cowslip shewing petallody.

Mr. C. L. BARNES, M.A., showed a copper token which had been discovered in the excavations made for the new buildings at the Manchester Grammar School. It was struck by Joannes Paula Lascaris, Grand Master of the Knights of Malta from 1636 to 1657, and bore what was probably a part of the inscription NON AES SED FIDES, sometimes found on old Maltese coins.

A paper by Dr. HENRY WILDE, F.R.S., was read, entitled "On Search-Lights for the Mercantile Marine,"

Mr. FRANCIS JONES, M.Sc., F.R.S.E., F.C.S., read a paper entitled "The Volatility of Sulphur and its Action on Water."

Mr. T. G. B. OSBORN, M.Sc., communicated "A Note on the Submerged Forest at Llanaber, Barmouth."

Miss MARY A. JOHNSTONE, B.Sc., read a paper entitled "On *Calamites* (*Calamitina*) *varians*, Sternb., var. *insignis*, Weiss."

Mr. T. A. COWARD, F.Z.S., made a communication, entitled "The Smelt in Rostherne Mere."

These papers are printed in full in the *Memoirs*.

MANCHESTER

LITERARY AND PHILOSOPHICAL SOCIETY.

Annual Report of the Council, April, 1912.

The Society had at the beginning of the session an ordinary membership of 150. Since then eighteen new members have joined the Society, eleven members have resigned, and three members, Sir W. J. Crossley, M.I.Mech.E., Mr. W. W. Kirkman, and Professor Osborne Reynolds, LL.D., F.R.S., have died. Thus, at the end of the session, there are 154 ordinary members of the Society. The deaths of Sir Joseph Dalton Hooker, O.M., G.C.S.I., C.B., D.C.L., F.R.S., and Professor A. Ladenburg, Ph.D., have removed two names from the roll of honorary members of the Society. Memorial notices of these gentlemen will be printed with this report in the *Memoirs and Proceedings*.

During the past session the average attendance at the meetings of the Society has been 22·5, as compared with an average attendance of 21 at the two preceding sessions.

Twenty-five papers have been read at the meetings during the session; and fifteen shorter communications have been made.

The Society commenced the session with a balance in hand, from all sources, of £304. 7s. 8d., made up as follows :—

At the credit of	General Fund	£62	11	6
,, ,,	Wilde Endowment Fund	149	12	4
,, ,,	Joule Memorial Fund	92	3	10
Balance 31st March, 1911		£304	7	8

At the close of the session the total balance in hand amounted to £400. 7s. 10d., the amounts standing at the credit of the various accounts on the 31st March, 1912, being:—

At the credit of General Fund	£46	14	7
,, ,, Wilde Endowment Fund	253	14	7
,, ,, Joule Memorial Fund	99	18	8
Balance 31st March, 1912	£400	7	10

The Wilde Endowment Fund, kept as a separate banking account, shows a balance due to the Fund of £253. 14s. 7d. as compared with a balance in hand of £149. 12s. 4d. at the end of the last financial year. The receipts for the year 1911-12 were slightly more than the receipts for the year 1910-11.

The Librarian reports that during the session 669 volumes have been stamped, catalogued and pressmarked; 646 of these were serials, and 23 were separate works. 248 catalogue cards were written, 184 for serials, and 64 for separate works. The total number of volumes catalogued to date is 33,751, for which 11,979 cards have been written.

The library continues to be satisfactorily used for reference purposes. 274 volumes have been borrowed from the library during the past twelve months, an increase of 89 on the number borrowed during the previous year.

The number of volumes bound during the year has been 226, in 189 covers. The amount of binding for the previous session was 214 volumes bound in 167.

The additions to the library for the session amounted to 856 volumes, 706 serials, and 150 separate works. The donations (exclusive of the usual exchanges) were 148 volumes and 158 dissertations; 2 volumes were purchased, in addition to those regularly subscribed to.

New exchanges have been arranged with the Remeis-Sternwarte (*Veröffentlichungen*), Bamberg; Rijks Herbarium (*Mededeelingen*), Leiden; Teyler's Godgeleerd Genootschap (*Verhandelingen*), Haarlem; the Society of Chemical Industry (*Journal of*), London; *The Micrologist*, Manchester; and the University Observatory (*Contributions*), Princeton, New Jersey, U.S.A.

In August the new '*Catalogue of Serials in the Library*,' the progress of which was referred to in the last Report of the Council, was issued, and provides a well-arranged and indexed list of the Society's large collection of serial publications.

Lack of the space necessary for the proper provision of the large quantity of literature which is continually being added to the Society's library greatly hampers the accessibility and satisfactory exhibition of the books.

Mr. FRANCIS NICHOLSON, F.Z.S., has presented to the Society a letter written by John Dalton, to Elihu Robinson, of Eaglesfield, near Cockermouth, soon after he had become a resident in Manchester, where, in 1793, he had been appointed Tutor in Mathematics and Natural Philosophy at the "Manchester Academy," now "Manchester College," Oxford. The letter contains probably the earliest account of that peculiarity of vision known as colour-blindness. Mr. THOMAS THORP, F.R.A.S., has also added to the donations during the session by presenting to the Society a crossed transparent grating constructed by himself.

The publication of the Society's *Memoirs and Proceedings* has been continued under the supervision of the Editorial Committee.

The Council have received with regret the resignation of Mr. A. P. Hunt, B.A., Assistant Secretary and Librarian to the Society, who has been appointed Librarian of the Edgar Allen Library in the University of Sheffield. Mr. R. F. Hinson has been appointed Assistant Secretary and Librarian in his place.

During the summer the tomb of John Dalton, in Ardwick Cemetery, was renovated at a cost of £10.

The Committees appointed by the Council during the year were as follows:—

House and Finance.

The President.	Mr. F. Nicholson.
Mr. C. L. Barnes.	Mr. W. H. Todd.
Mr. R. L. Taylor.	Dr. H. G. A. Hickling.

Editorial.

The President.	Professor E. Rutherford.
Professor S. J. Hickson.	Mr. R. L. Taylor.
Dr. H. G. A. Hickling.	The Assistant Secretary.

Wilde Endowment.

The President.	Mr. W. H. Todd.
Mr. Francis Jones.	Mr. R. L. Taylor.
Dr. H. G. A. Hickling.	

The hours during which the Society's rooms are open to members have been fixed as follows: Monday, Tuesday, Wednesday, Thursday, and Friday, 9-30 a.m. to 6-0 p.m.; Saturday, 9-30 a.m. to 1-0 p.m. These hours do not of course apply to the days on which the Society's rooms are officially closed.

The Council have concurred with a request by Dr. Henry Wilde, F.R.S., that the Wilde Lectures should be discontinued, and the amount provided therefor by the Trust Deed will fall into the Trust Fund and become general income of the Fund.

The President has been nominated to represent the Society at the 250th anniversary of the foundation of the Royal Society of London.

Sir Joseph Dalton Hooker, O.M., G.C.S.I., F.R.S., on December 10th, 1911, passed peacefully away in his sleep at the ripe age of 94. It is impossible in the compass of a short obituary notice to do justice to the scientific work accomplished during so long a lifetime of exceptional activity, for up to the very end of it Sir Joseph Hooker was engaged in the publication of valuable contributions to Science.

The distinguished son of Sir William Hooker, Regius Professor of Botany in the University of Glasgow, and subsequently Director of the Royal Gardens at Kew, Sir Joseph had special facilities for the study of that science to which he devoted his rare mental faculties with such enthusiasm throughout his long lifetime. Like his friend Charles Darwin, he was enormously influenced at the outset of his career by the stimulus so beneficial to all naturalists of extensive travel, being fortunate enough to accompany, as assistant surgeon and botanist, Sir James Ross on his Antarctic expedition in 1839. Three years before, Darwin had returned on the "Beagle," and

Hooker, who was privileged to read the proof sheets of Darwin's *Journal* before he set out in the "Erebus," relates with the modesty of a truly great man how they impressed him profoundly, and even despairingly, with the variety of acquirements, mental and physical, required in a naturalist who should follow in Darwin's footsteps, while they inspired him to enthusiasm in the desire to travel and observe. No one could have made better use of his opportunities, as the six volumes of his *Flora Antarctica* sufficiently testify. But the publication of this monumental work was interrupted by an eventful journey to India in 1847 to study the sub-tropical vegetation of the Himalayas. The story of this expedition, lasting for three years, is told in the *Himalayan Journals*, published in 1854. From 1855 to 1865, Joseph Hooker was Assistant Director of the Royal Gardens at Kew, and after his father's death, in 1865, he held the post of Director for twenty years. But though his time was greatly engrossed by official duties, this period of his life was marked by the publication of many volumes of classic importance, such as the *Genera Plantarum*, compiled in conjunction with Mr. Bentham, and *The Flora of British India* in conjunction with Mr. Thompson, the seventh and last volume of which was not completed until 1897, so that Sir Joseph Hooker, though relinquishing the office of Director of Kew in 1883, continued his heavy labours unflinchingly in his retirement. He similarly continued to edit the *Icones Plantarum* until 1889, and *The Botanical Magazine* until 1902.

Though it was only for a short time that he held the post of Botanist to the Geological Survey, Sir Joseph Hooker continued throughout his life to take an active interest in the study of fossil plants and he published many papers on palæobotanical subjects.

One of the most memorable features of Sir Joseph Hooker's life was his close and friendly intercourse, extending over forty years, with Charles Darwin, who cordially welcomed Hooker's frank criticism of his early speculations on the origin of species. Indeed, in his letters, Darwin frequently refers to the help received from Sir Joseph Hooker, and undoubtedly Hooker's espousal of the Darwinian theory of evolution after the publication of the *Origin of Species* did much to gain acceptance for it among botanists and drew these two great naturalists ever closer together.

Throughout this long period of his active scientific career unsought but well-deserved honours were heaped upon Sir Joseph Hooker, one of the last, and certainly not the least, being the Order of Merit, which was conferred upon him on his ninetieth birthday. Hale and hearty still, Hooker took an active part in the following year in the Darwin-Wallace celebrations of the Linnean Society, and similarly in 1909 at Cambridge, at the commemoration of the centenary of the birth of Charles Darwin.

Twenty years ago, Sir Joseph Hooker was elected an honorary member of our Society, and in 1898 he was awarded the Wilde Medal. F. E. W.

WILLIAM WRIGHT KIRKMAN, whose death took place at The Grange, Timperley, Cheshire, on the 29th of May, 1911, in his 69th year, was the eldest son of the late Reverend T. P. Kirkman, F.R.S., Rector of Croft-cum-Southworth, near Warrington, one of our honorary members, from whom we had many papers, mostly on mathematical subjects.

His son, the subject of this notice, was elected a member of the Society on November 12th, 1895. He was a particularly well-read man, and by members of his profession he was considered a very able and sound lawyer. Though he made no communications at any of our meetings, he wrote an excellent obituary notice of his father, which appeared in our *Memoirs* Vol. 9, 4th Series). F. N.

Osborne Reynolds was born at Belfast, August 23rd, 1842. He came of a clerical family. His grandfather, the Rev. Osborne S. Reynolds, had been a scholar of Gonville and Caius College, Cambridge, and afterwards rector of Debach with Boulge, Suffolk. His father, the Rev. Osborne Reynolds, was thirteenth wrangler in 1837 (the year of Green and Sylvester), subsequently Fellow of Queens' College, Principal of the Belfast Collegiate School, headmaster of Dedham Grammar School, Essex, and finally, in his turn, rector of Debach. It was to his father that he owed his early education, first at the Dedham School, and afterwards privately. After a short period with a tutor he entered, in 1861, the workshop of Mr. E. Hayes, mechanical engineer, at Stoney Stratford, in order "to learn in the shortest time possible how work should be done, and . . . to be made a working mechanic before going to Cambridge." In 1863 he went to Cambridge, to his father's College, Queens', of which he became a Fellow in 1867, after graduating as seventh wrangler. Immediately afterwards he entered the office of John Lawson, civil engineer, of London.

In 1868 he was elected to the newly instituted professorship of engineering in the Owens College, which he held until his practical retirement in 1905. This was almost the first chair of the kind in England, although similar professorships had existed for some time in Scotland, and had been held by such men as James Thomson, Rankine, and Fleeming Jenkin. It is possible, indeed, that Reynolds was influenced to some extent by the tradition of these chairs. With Rankine, at any rate, for whom he professed the greatest admiration, he had strong affinities, in the wide range of his scientific interests, in the clearness of his intuitions, and in the courage and tenacity with which he attacked difficult and complicated problems.

Reynolds became a member of our Society in 1869, and from that time onwards was a constant attendant at its meetings. He took an active share in its business, and contributed many important papers. He was Secretary from 1874 to 1883, and

President for the term 1888-9. He was the author of the Joule memorial volume, which was published by the Society in 1892, and was the leading spirit in the movement for a public monument to Joule, which resulted in the beautiful statue by Gilbert now in the Town Hall.

About the year 1899 the Cambridge University Press suggested to Reynolds that a collected edition of his scientific writings would be valuable, and offered to undertake the publication. This signal compliment was highly appreciated by him, and in due course two weighty volumes appeared. The range of subjects covered is so wide that possibly no two authorities would agree in selecting what they considered most important or most characteristic. The papers are all marked by great independence and originality of view, and by the clearness of insight with which essential principles are discerned and irrelevant details left aside. Several of his memoirs on engineering subjects have taken rank as classics—*e.g.* the work on Lubrication, on Turbulent Flow in Pipes, and in connection with the Mechanical Equivalent of Heat. Among the shorter writings mention may be made of the papers on the Refraction of Sound, on Group-Velocity of Waves, and on Dilatancy, where simple and convincing explanations are given of phenomena well known indeed, but previously obscure.

In the mind of Reynolds there appears to have been a connection, partly intrinsic, and partly as regards the scientific principles and methods involved, between such diverse subjects as thermal transpiration, turbulent flow, and dilatancy, on all of which he had worked at one time or other. And it was apparently through this connection that he was led to the remarkable speculation on "The Sub-Mechanics of the Universe," which marked the close of his scientific career, and which constitutes the final volume of his collected papers. Unfortunately, illness had begun to impair his powers of exposition, and the memoir as it stands is affected with omissions and discontinuities which render it difficult to follow. No one who has studied the work of Reynolds can doubt that it embodies ideas of value, but it is to be feared that their significance will hardly be appreciated until some future investigator, treading a parallel path, recognises them with the true sympathy of genius, and puts them in their proper light.

Prof. Reynolds, owing to the failing state of his health, withdrew from the active work of his chair in 1905. His last years were spent in retirement at Watchet, Somerset, where he died on February 21st, 1912.

He had been a Fellow of the Royal Society since 1877, and received a Royal Medal in 1888. He was made an Honorary Fellow of Queens' College, Cambridge, in 1881, and received the Degree of LL.D. from the University of Glasgow in 1884. An admirable portrait by Collier, presented by scientific friends and admirers from all parts of the kingdom, hangs in the hall of the Manchester University. H. L.

Sir William John Crossley was the second son of Major Francis Crossley, of Glenburn, Dunmurry, County Antrim. His father, formerly of the East India Company's service, came of an old Lancashire family.

Born on April 22nd, 1844, at Dunmurry, William John Crossley was educated at the Royal School, Dungannon, and afterwards at Bonn. He then commenced, at the age of nineteen, an apprenticeship at the engineering works of Sir William G. Armstrong, at Elswick, and there received a four years' course of training. In 1867 he commenced business in partnership with his brother Francis, who had purchased an india-rubber machinery works in Manchester, but for some years the brothers did not meet with much success. In addition, they paid some attention to improvements in flax-scutching machinery. Their doggedness, however, was rewarded. In 1876 they secured the English patent rights of the Otto gas-engine, and, setting themselves to improve upon Dr. Otto's designs, the business prospered to such an extent as to necessitate the provision of larger premises, which they procured at Openshaw.

Sir William was a man of strong views, broad-minded, adhering strictly to what he considered to be right. He married, in 1876, Miss Mabel Gordon, daughter of Dr. Francis Anderson, Inspector-General of Hospitals in India. In 1875 he was elected a member of the Institution of Mechanical Engineers. He was well known for the assistance and active co-operation he was always prepared to give to philanthropic and sociological work. To his munificence is due the founding of the Crossley Sanatorium, for the reception of consumptive patients, at Delamere. Of this institution he became chairman. He financed an increase in the accommodation of the Convalescent Home at Bowdon, Cheshire. He was also chairman of the Boys' and Girls' Refuges at Strangeways; chairman of the Manchester Hospitals for Consumptives; President of the Young Men's Christian Association, Manchester; and Treasurer of the United Kingdom Alliance. He was a Justice of the Peace for Manchester and for the County of Cheshire; and in 1901 he was elected a member of the Cheshire County Council. He also was one of the promoters of the Manchester Ship Canal, and became one of the Board of Directors of the Ship Canal Company. In 1903 the Corporation of Manchester conferred upon him the honorary freedom of the city.

Despite the many demands upon his energies Sir William found time to devote himself to parliamentary duties, and he sat as Member for the Altrincham Division of Cheshire from 1906 to 1910. He was re-elected at the contest in January, 1910, but he lost the seat in December of the same year. In 1909 King Edward conferred a baronetcy upon him.

Sir William was a member of this Society from 1895 until he passed away on Thursday, October 12th, 1911, in a Manchester Nursing Home, after an illness of but a few days' duration.

R. F. H.

Professor Albert Ladenburg, organic chemist, was born 2nd July, 1842, at Mannheim. He studied at Heidelberg, at Bonn and at Paris. In 1870 he became privat-docent in the University of Heidelberg, and in 1874 was elected Professor of Chemistry in the University of Kiel. For many years he was Professor of Chemistry at Breslau, where he died. All who were brought into contact with Ladenburg were attracted by the intense interest he showed in all scientific problems, and by his vitality and social qualities. He was universally popular.

He became known to a wide circle of readers through his "History of the Development of Chemistry since the Time of Lavoisier," which has gone through several German editions and has been translated into English by Dr. Dobbin. This work contains a very concise account of the development of modern chemistry (with copious references to original authorities) and is eminently free from "national" bias.

His "Theory of Aromatic Compounds" contains a clear account of Ladenburg's important contributions to the constitution of benzene and naphthalene derivatives, with a reasoned criticism of the defects of Kekule's hexagon formula for benzene.

Ladenburg's "Handbook of Chemistry," in 3 volumes, is a well-known text-book. H. B. D.

MANCHESTER LITERARY AND

Dr. *W. Henry Todd, Treasurer, in Account with the*

	£ s. d.	£ s. d.
To Balance, 1st April, 1911		154 15 4
To Members' Subscriptions:—		
Half Subscriptions, 1910-11, 2 at £1. 1s. 0d	2 2 0	
,, 1911-12, 17 ,, ,,	17 17 0	
Subscriptions:— 1908-9, 1 ,, £2. 2s. 0d.	2 2 0	
,, 1909-10, 1 ,, ,,	2 2 0	
,, 1910-11, 9 ,, ,,	18 18 0	
,, 1911-12, 117 ,, ,,	245 14 0	
,, 1911-12, 1 ,, £2. 2s. 2d.	2 2 2	
		290 17 2
To Transfers from the Wilde Endowment Fund		83 12 0
To Sale of Publications		13 10 1
To Sale of Catalogues		5 5 0
To Dividends:—		
Natural History Fund	57 13 6	
Joule Memorial Fund	7 5 10	
		64 19 4
To Income Tax Refunded:—		
Natural History Fund	3 11 6	
Joule Memorial Fund	0 9 0	
Wilde Endowment Fund	20 11 3	
		24 11 9
		£637 10 8

NATURAL HISTORY

	£ s. d.
To Balance, 1st April, 1911	11 4 8
To Dividends on £1,225 Great Western Railway Company's Stock	57 13 6
To Remission of Income Tax, 1911	3 11 6
	£72 9 8

JOULE MEMORIAL

	£ s. d.
To Balance, 1st April, 1911	92 3 10
To Dividends on £258 Loan to Manchester Corporation	7 5 10
To Remission of Income Tax, 1911	0 9 0
	£99 18 8

WILDE ENDOWMENT

	£ s. d.
To Balance, 1st April, 1911	149 12 4
To Dividends on £7,500 Gas Light and Coke Company's Ordinary Stock	334 5 10
To Remission of Income Tax, 1911	20 11 3
To Bank Interest	2 5 1
	£506 14 6

PHILOSOPHICAL SOCIETY.

Society, from 1st April, 1911, to 31st March, 1912. **Cr.**

	£ s. d.	£ s. d.
By Charges on Property :—		
Chief Rent (Income Tax deducted)	12 3 4	
Income Tax	0 15 0	
Insurance against Fire	11 0 0	
		23 18 4
By House Expenditure :—		
Coals, Gas, Electric Light, Water, &c.	31 13 10	
Tea, Coffee, &c., at Meetings	12 10 7	
Cleaning, Sweeping Chimneys, &c.	4 3 10	
Replacements of mantles, crockery, dusters, etc.	3 9 6	
		51 17 9
By Administrative Charges :—		
Housekeeper	65 0 0	
Postages, and Carriage of Parcels and of "Memoirs"	30 15 7½	
Stationery, Cheques, Receipts, and Engrossing	3 0 7	
Printing Circulars, Reports, &c.	12 8 6	
Extra attendance at Meetings, and during housekeeper's holidays	3 11 6	
Insurance against Liability	0 12 0	
Miscellaneous Expenses	1 0 0½	
Fares of Candidates, Advertising, &c.	8 11 1	
		124 19 4
By Renovating Dalton Tomb	.. ..	10 0 0
By Publishing :—		
Printing "Memoirs and Proceedings"	128 0 3	
Illustrations for "Memoirs" (except Nat. Hist. papers)	5 10 6	
		133 10 9
By Library :—		
Books and Periodicals (except those charged to Natural History Fund)	50 10 7	
Periodicals formerly subscribed for by the Microscopical and Natural History Section	3 3 0	
		53 13 7
By Natural History Fund :—		
(Items shown in the Balance Sheet of this Fund below)	.. ..	72 6 5
By Joule Memorial Fund :—		
(No expenditure)	.. ..	0 0 0
By Wilde Endowment Fund (Income Tax refunded)	.. ..	20 11 3
By Balance at Williams Deacon's Bank, 1st April, 1912	136 13 3	
,, ,, in Treasurer's hands	10 0 0	
		146 13 3
		£637 10 8

FUND, 1911—1912. (Included in the General Account, above.)

	£ s. d.
By Natural History Books and Periodicals	57 16 8
By Illustrations for papers on Nat. Hist. in "Memoirs"	6 8 0
By Binding Books	8 1 9
By Balance, 1st April, 1912	0 3 3
	£72 9 8

FUND, 1911—1912. (Included in the General Account, above.)

	£ s. d.
(No expenditure).	
By Balance, 1st April, 1912	99 18 8
	£99 18 8

FUND, 1911—1912.

	£ s. d.
By Assistant Secretary's Salary, April, 1911, to September, 1911	75 0 0
By Assistant Secretary's Salary. September, 1911, to March, 1912	70 0 0
By Maintenance of Society's Library :—	
Binding and Repairing Books	24 1 9
By Repairs and Improvements to Society's Premises	0 6 2
By Transfers to Society's Funds	83 12 0
By Balance at District Bank, 1st April, 1912	253 14 7
	£506 14 6

NOTE.—The Treasurer's Accounts of the Session 1911-1912 have been endorsed as follows:

April 9th, 1912. 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. 1,564); £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 Declarations of Trust.

Leases and Conveyances dated as follow:—

22nd Sept., 1797.
23rd Sept., 1797.
25th Dec., 1799.
,, ,, ,,
22nd Dec., 1820.
23rd Dec., 1820.

Declarations of Trust:—

24th June, 1801.
23rd Dec., 1820.
30th April, 1851.
8th Jan., 1878.

We have also verified the balances of the various accounts with the bankers' pass books.

(Signed) { H. F. SCHMITZ.
GEO. P. VARLEY.

THE COUNCIL
AND MEMBERS
OF THE
MANCHESTER
LITERARY AND PHILOSOPHICAL SOCIETY.

Corrected to November 26th, 1912.

President.
F. E. WEISS, D.Sc., F.L.S.

Vice-Presidents.
FRANCIS JONES, M.Sc., F.R.S.E., F.C.S.
ERNEST RUTHERFORD, M.A., D.Sc., F.R.S.
ARTHUR SCHUSTER, Sc.D., Ph.D., F.R.S.
WILLIAM BURTON, M.A., F.C.S.

Secretaries.
R. L. TAYLOR, F.C.S., F.I.C.
GEORGE HICKLING, D.Sc.

Treasurer.
W. HENRY TODD.

Librarian.
C. L. BARNES, M.A.

Other Members of the Council.
SYDNEY J. HICKSON, M.A., D.Sc., F.R.S.
T. A. COWARD, F.Z.S.
FRANCIS NICHOLSON, F.Z.S.
G. ELLIOT SMITH, M.A., M.D., F.R.S.
W. W. HALDANE GEE, B.Sc., M.Sc.Tech., A.M.I.E.E.
BERTRAM PRENTICE, Ph.D., D.Sc.

Assistant Secretary and Librarian.
R. F. HINSON.

ORDINARY MEMBERS.

Date of Election.

1911, April 4. Adamson, Arthur, M.Sc.Tech., A.R.C.S., Lecturer in Physics in the Municipal School of Technology, Manchester. *Technical School, Sackville Street, Manchester.*

1901, Dec. 10. Adamson, Harold. *Oaklands Cottage, Godley, near Manchester.*

1912, Oct. 15. Adamson, R. Stephen, M.A., B.Sc., Lecturer in Botany in the Victoria University of Manchester. *The University, Manchester.*

1870, Dec. 13. Angell, John, F.C.S., F.I.C. 6, *Beacons-Field, Derby Road, Withington, Manchester.*

1865, Nov. 14. Bailey, Charles, M.Sc., F.L.S. *Haymesgarth, Cleeve Hill, S.O., Gloucestershire.*

1888, Feb. 7. Bailey, Alderman Sir William H., M.I.Mech.E. *Sale Hall, Sale, Cheshire.*

1895, Jan. 8. Barnes, Charles L., M.A. 151, *Plymouth Grove, Manchester.*

1903, Oct. 20. Barnes, Jonathan, F.G.S. *South Cliff House*, 301, *Great Clowes Street, Higher Broughton, Manchester.*

1910, Oct. 18. Beattie, Robert, D.Sc., Lecturer in Electrotechnics in the University of Manchester. *The University, 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.*

1875, Nov. 16. Boyd, John. *Barton House*, 11, *Didsbury Park, Didsbury, Manchester.*

1889, Oct. 15. Bradley, Nathaniel, F.C.S. *Sunnyside, Whalley Range, Manchester.*

1912, Oct. 15. Brierley, W.B., M.Sc., Lecturer in Economic Botany in the Victoria University of Manchester. *The University, Manchester.*

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.*

1910, Nov. 1. Broome, James S., Science Teacher in the Salford Secondary School. 18, *Seedley Park Road, Pendleton, Manchester.*

1886, April 6. Brown, Alfred, M.A., M.D. *Sandycroft, Higher Broughton, Manchester.*

1889, Jan. 8. Brownell, Thomas William, F.R.A.S. 64, *Upper Brook Street, Manchester.*

Date of Election.

1889, Oct. 15. Budenberg, C. F., M.Sc., M.I.Mech.E. *Bowdon Lane. Marple, Cheshire.*

1911, Jan. 10. Burt, Frank Playfair, D.Sc.(Lond.), Assistant Lecturer and Demonstrator in Chemistry in the Victoria University of Manchester. 5, *Beacons-Field, Derby Road, Withington, Manchester.*

1906, Feb. 27. Burton, Joseph, A.R.C.S. Dublin. *Tile Works, Clifton Junction, near Manchester.*

1894, Nov. 13. Burton, William, M.A., F.C.S. *The Hollies, Clifton Junction, near Manchester.*

1911, Oct. 31. Butterworth, Charles F. *Waterloo, Poynton, Manchester.*

1904, Oct. 18. Campion, George Goring, L.D.S. 264, *Oxford Street, Manchester.*

1907, Jan. 15. Carpenter, H. C. H., M.A., Ph.D., Professor of Metallurgy in the University of Manchester. 11, *Oak Road, Withington, Manchester.*

1899, Feb. 7. Chapman, D. L., M.A., Fellow of Jesus College, Oxford. *Jesus College, Oxford.*

1901, Nov. 26. Chevalier, Reginald C., M.A., Mathematical Master at the Manchester Grammar School. 3, *Fort Road, Sedgley Park, Prestwich, Manchester.*

1907, Nov. 26. Clayton, Robert Henry, B.Sc., Chemist. 1, *Parkfield Road, Didsbury, Manchester.*

1895, April 30. Collett, Edward Pyemont. 8, *St. John Street, Manchester.*

1911, May 9. Cook, Gilbert, M.Sc., A.M.Inst.C.E., Vulcan Research Fellow in Engineering in the University of Manchester. 8, *Clarendon Road, Garston, Liverpool.*

1903, Oct. 20. Core, William Hamilton, M.Sc. *Groombridge House, Withington, Manchester.*

1910, Oct. 18. Cotton, Robert, M.Sc., Demonstrator in Engineering in the University of Manchester. *Westholme, Devonshire Road, Pendleton, Manchester.*

1906, Oct. 30. Coward, H. F., D.Sc., Assistant Lecturer in Chemistry in the University of Manchester. *Municipal School of Technology, Sackville Street, Manchester.*

1906, Nov. 27. Coward, Thomas Alfred, F.Z.S. *Brentwood, Bowdon, Cheshire.*

1908, Nov. 3. Cramp, William, M.Sc.Tech., M.I.E.E., Consulting Engineer. 20, *Mount Street, Manchester.*

1910, Oct. 4. Crewe, F. H., Assistant Science Master in the Municipal Secondary School, Whitworth Street. *Glengarth, Woodford Road, Bramhall.*

1911, April 4. Darwin, C. G., B.A., Reader in Mathematical Physics in the University of Manchester. *The University, Manchester.*

Date of Election.

1895, April 9. Dawkins, W. Boyd, M.A., D.Sc., F.R.S.. Honorary 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. *The University, Manchester.*

1887, Feb. 8. Dixon, Harold Baily, M.A., M.Sc., F.R.S., F.C.S., Professor of Chemistry in the Victoria University of Manchester. *The University, Manchester.*

1906, Oct. 30. Edgar, E. C., D.Sc., Assistant Lecturer and Demonstrator in Chemistry in the University of Manchester. *The University, Manchester.*

1910, Oct. 18. Evans, Evan Jenkin, B.Sc., Assistant Lecturer and Demonstrator in Physics in the University of Manchester. *The University, Manchester.*

1912. Oct. 15. Fairlie, D. M., M.Sc., Demonstrator in Electro-Chemistry, The Municipal School of Technology, Manchester. *The Municipal School of Technology, Manchester.*

1912, Feb. 6. Forder, H. G., B.A., Mathematical Master, Hulme Grammar School. *Hulme Grammar School, Oldham.*

1908, Jan. 28. Fox, Thomas William, M.Sc.Tech., Professor of Textiles in the School of Technology, Manchester University. 15, *Clarendon Crescent, Eccles.*

1912, Oct. 15. Garnett, J. C. Maxwell, M.A., Principal of the Municipal School of Technology, Manchester. *The Municipal School of Technology, Manchester.*

1909, Mar. 23. Gee, W. W. Haldane, B.Sc., M.Sc.Tech., A.M.I.E.E., Professor of Pure and Applied Physics in the School of Technology, Manchester University. *Oak Lea, Whalley Avenue, Sale.*

1910, Nov. 29. Geiger, Hans, Ph.D., *Physikalisch Technische Reichsanstalt, Charlottenburg, Marchstrasse, Germany.*

1907, Oct. 15. Gravely, F. H., M.Sc. *Natural History Dept., Indian Museum, Calcutta.*

1907, Oct. 29. Gwyther, Reginald Felix, M.A., Secretary to the Joint Matriculation Board. 21, *Booth Avenue, Withington, Manchester.*

1911, Oct. 3. Hassé, H. R., M.A., M.Sc., Lecturer in Mathematics in the University of Manchester. 100, *Ladybarn Lane, Fallowfield, Manchester.*

Date of Election.

1902, Jan. 7. Hewitt, David B., M.D. *Grove Mount, Davenham, Cheshire.*

1907, Oct. 15. Hickling, H. George A., D.Sc., Assistant Lecturer and Demonstrator in Geology in the University of Manchester. *Glenside, Marple Bridge, near Stockport*

1895, Mar. 5. Hickson, Sydney J., M.A., D.Sc., F.R.S., Professor of Zoology in the Victoria University of Manchester. *The University, Manchester.*

1884, Jan. 8. Hodgkinson, Alexander, M.B., B.Sc. 18, *St. John Street, Manchester.*

1909, Jan. 12. Hoffert, Hermann Henry, D.Sc. (Lond.), A.R.S.M., His Majesty's Inspector of Schools. *Lime Grove, Brooklands, Sale.*

1909, Nov. 2. Holland, Sir Thomas H., K.C.I.E., D.Sc., F.R.S., Professor of Geology and Mineralogy in the University of Manchester, late Director of the Geological Survey of India. *Westwood, Alderley Edge, Cheshire.*

1905, Nov. 14. Holt, Alfred, M.A., D.Sc., Research Fellow of the University of Manchester. *Dowsefield, Allerton, Liverpool.*

1898, Nov. 29. Hopkinson, Sir Alfred, K.C., M.A., LL.D., Vice-Chancellor of the Victoria University of Manchester. *Fairfield. Victoria Park, Manchester.*

1896, Nov. 3. Hopkinson, Edward, M.A., D.Sc., M.Inst.C.E. *Ferns, Alderley Edge, Cheshire.*

1909, Feb. 9. Howles, Frederick, M.Sc., Analytical and Research Chemist. *Glenluce, Waterpark Road, Broughton Park, Manchester.*

1889, Oct. 15. Hoyle, William Evans, M.A., D.Sc., F.R.S.E., Director of the Welsh National Museum, Cardiff. *City Hall, Cardiff.*

1907, Oct. 15. Hübner, Julius, M.Sc.Tech., F.I.C., Lecturer in the Faculty of Technology in the University of Manchester. *Linden, Cheadle Hulme, Cheshire.*

1899, Oct. 17. Ingleby, Joseph, M.I.Mech.E. *Springfield, Holly Road, Wilmslow, near Manchester.*

1901, Nov. 26. Jackson, Frederick. 14, *Cross Street, Manchester.*

1870, Nov. 1. Johnson, William H., B.Sc. *Woodleigh, Altrincham.*

1911, Oct. 3. Johnstone, Mary A., B.Sc.(Lond.), Headmistress of the Municipal Secondary School for Girls, Whitworth Street, Manchester. 11, *Birchvale Drive, Romiley, near Manchester.*

Date of Election.

1878, Nov. 26. Jones, Francis, M.Sc., F.R.S.E., F.C.S. *Manchester Grammar School*, and 17, *Whalley Road, Whalley Range, Manchester.*

1886, Jan. 12. Kay, Thomas, J.P. *Moorfield, Stockport, Cheshire.*

1903, Feb. 3. Knecht, Edmund, Ph.D., Professor of Chemistry in the School of Technology, Manchester University. *Beech Mount, Marple, Cheshire.*

1893, Nov. 14. Lamb, Horace, M.A., LL.D., D.Sc., Sc.D., F.R.S., Professor of Mathematics in the Victoria University of Manchester. 6, *Wilbraham Road, Fallowfield, Manchester.*

1909, Nov. 2. Lang, William H., M.B., C.M., D.Sc., F.R.S., F.L.S., Barker Professor of Cryptogamic Botany in the University of Manchester. 2, *Heaton Road, Withington, Manchester.*

1902, Jan. 7. Lange, Ernest F., M.I.Mech.E., A.M.Inst.C.E., M.I. & S. Inst., F.C.S. *Fairholm*, 3, *Willow Bank, Fallowfield, Manchester.*

1911, Jan. 10. Lankshear, Frederick Russell, B.A. (New Zeal.), Demonstrator in Chemistry in the Victoria University of Manchester. *The University, Manchester.*

1910, Oct. 18. Lapworth, Arthur, D.Sc., F.R.S., F.I.C., Senior Lecturer in Chemistry in the University of Manchester. 30, *Amherst Road, Withington, Manchester.*

1904, Mar. 15. Lea, Arnold W. W., M.D. 246, *Oxford Road, Manchester.*

1907, Oct. 29. Leigh, Harold Shawcross. *Brentwood, Worsley.*

1908, Oct. 20. Liebert, Martin, Ph.D., Managing Director of Meister Lucius and Brüning, Ltd., Manchester. 1, *Lancaster Road, Didsbury, Manchester.*

1912, Nov. 12. Lindsey, Marjorie, B.Sc., Research Student in the Victoria University of Manchester. *3, Demesne Road, Whalley Range, Manchester.*

1912, May 7. Loewenfeld, Kurt, Ph.D. *Fern Bank, Ogden Road, Bramhall, Cheshire.*

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.*

1866, Nov. 13. McDougall, Arthur, B.Sc. *The Cottage, Holly Road, Bramhall, near Stockport.*

Date of Election.

1910, Oct. 18. McDougall, Robert, B.Sc. *City Corn Mills, German Street, Manchester.*

1912, Oct. 15. McFarlane, John, M.A. (Edin.), B.A. (Cantab), M.Com. (Manc.), Lecturer in Geography in the Victoria University of Manchester. *The University, Manchester.*

1905, Oct. 31. McNicol, Mary, M.Sc. 182, *Upper Chorlton Road, Manchester.*

1904, Nov. 1. Makower, Walter, B.A., D.Sc. (Lond.), Lecturer in Physics in the University of Manchester. *Maylands, Brook Road, Fallowfield, Manchester.*

1902, Mar. 4. Mandleberg, Goodman Charles. *Redclyffe, Victoria Park, Manchester.*

1910, Oct. 18. Mangan, Joseph, M.A., Lecturer in Economic Zoology in the University of Manchester. *The University, Manchester.*

1911, Oct. 31. March, Margaret Colley, M.Sc. *The University, Manchester.*

1901, Dec. 10. Massey, Herbert. *Ivy Lea, Burnage, Didsbury, Manchester.*

1864, Nov. 1. Mather, Sir William, P.C., M.Inst.C.E., M.I.Mech.E. *Iron Works, Salford.*

1912, Nov. 26. Melland, Edward. *Kia Ora, Hale, Cheshire.*

1873, Mar. 18. Melvill, James Cosmo, M.A., D.Sc., F.L.S. *Meole Brace Hall, Shrewsbury.*

1894, Feb. 6. Mond, Robert Ludwig, M.A., F.R.S.E., F.C.S. *Winnington Hall, Northwich, Cheshire.*

1911, May 9. Moseley, Henry Gwyn Jeffreys, B.A., Lecturer in Physics in the University of Manchester. *Physical Laboratories, The University, Manchester.*

1911, Oct. 3. Mumford, A. A., M.D. Medical Officer, Manchester Grammar School. 44, *Wilmslow Road, Withington, Manchester.*

1912, Nov. 26. Myers, J. E., M.Sc., Beyer Fellow and Assistant Lecturer in Chemistry in the Victoria University of Manchester. *The University, Manchester.*

1908, Jan. 28. Myers, William, Lecturer in Textiles in the School of Technology, Manchester University. *Acresfield, Gatley, Cheshire.*

1873, Mar. 4. Nicholson, Francis, F.Z.S. *The Knoll, Windermere, Westmorland.*

1900, April 3. Nicolson, John T., D.Sc., Professor of Engineering in the School of Technology, Manchester University. *Nant-y-Glyn, Marple, Cheshire.*

Date of Election.

1884, April 15. Okell, Samuel, F.R.A.S. *Overley, Langham Road, Bowdon, Cheshire.*

1892, Nov. 15. Perkin, W. H., Sc.D., Ph.D., M.Sc., F.R.S., Professor of Chemistry in the Victoria University of Manchester. *The University, Manchester.*

1901, Oct. 29. Petavel, J. E., B.A., D.Sc., F.R.S., Professor of Engineering in the Victoria University of Manchester. *The University, Manchester.*

1885, Nov. 17. Phillips, Henry Harcourt, F.C.S. *Lynwood, Turton, near Bolton, Lancs.*

1903, Dec. 15. Prentice, Bertram, Ph.D., D.Sc., Principal, Royal Technical Institute, Salford. *Isca Mount, Manchester Road, Swinton.*

1911, Oct. 17. Pring, J. N., D.Sc., Lecturer and Demonstrator in Electro-Chemistry in the University of Manchester. *The University, 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.*

1910, Oct. 4. Rhead, E. L., M.Sc.Tech., F.I.C., Lecturer on Metallurgy at the Municipal School of Technology, Manchester. *Stonycroft, Polygon Avenue, Levenshulme, Manchester.*

1912, Oct. 29. Roberts, A. W. Rymer, M.A., *Ellerbeck, Crook, near Kendal.*

1880, Mar. 23. Roberts, D. Lloyd, M.D., F.R.S.E., F.R.C.P. (Lond.), *Ravenswood, Broughton Park, Manchester.*

1911, Jan. 10. Robinson, Robert, D.Sc. (Vict.), Teacher of Chemistry in the Victoria University of Manchester. *Field House, Chesterfield.*

1910, Oct. 18. Rossi, Roberto, M.Sc., Student. *Physical Laboratory, The University, Manchester.*

1897, Oct. 19. Rothwell, William Thomas. *Heath Brewery, Newton Heath, near Manchester.*

1907, Oct. 15. Rutherford, Ernest, M.A., D.Sc., F.R.S., Langworthy Professor of Physics in the University of Manchester. 17, *Wilmslow Road, Withington, Manchester.*

Date of Election.

1911, Oct. 17. Sandiford, Peter, M.Sc. (Manc.), Ph.D. (Columbia), Lecturer and Demonstrator in Education in the University of Manchester. *The University, Manchester.*

1909, Jan. 26 Schmitz, Hermann Emil, M.A., B.Sc., Physics Master at the Manchester Grammar School. 15, *Brighton Grove, Rusholme, Manchester.*

1873, Nov. 18. Schuster, Arthur, Sc.D., Ph.D., Sec.R.S., F.R.A.S., Honorary 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.*

1890, Nov. 4. Sidebotham, Edward John, M.A., M.B., M.R.C.S. *Erlesdene, Bowdon, Cheshire.*

1903, April 28. Sidebottom, Henry. *Woodstock, Bramhall, Cheshire.*

1910, Oct. 4. Smith, Grafton Elliot, M.A., M.D., F.R.S.. Professor of Anatomy in the University of Manchester. *The University, Manchester.*

1906, Nov. 27. Smith, Norman, D.Sc., Assistant Lecturer in Chemistry in the Victoria University of Manchester. *The University, Manchester.*

1896, Feb. 18. Spence, David. *Lowood, Hindhead, Haslemere, R.S.O., Surrey.*

1901, Dec. 10. Spence, Howard. *Audley, Broad Road, Sale, Cheshire.*

1904, Nov. 1. Stansfield, Herbert, D.Sc. (Lond.), A.I.E.E., Assistant Lecturer and Demonstrator in Physics in the University of Manchester. *The University, Manchester.*

1911, Oct. 17. Start, Laura, Lecturer in Art and Handicraft in the University of Manchester. *Moor View, Mayfield Road, Kersal, Manchester.*

1897, Nov. 30. Stromeyer, C. E., M.Inst.C.E. *Steam Users' Association,* 9, *Mount Street, Albert Square, Manchester.*

1910, Oct. 18. Tattersall, Walter Medley, D.Sc., Keeper of the Manchester Museum. *The Museum, University, Manchester.*

1895, April 9. Tatton, Reginald A., M.Inst.C.E., Engineer to the Mersey and Irwell Joint Committee. *Manor House Chelford, Cheshire.*

1893, Nov. 14. Taylor, R. L., F.C.S., F.I.C. *Municipal Secondary School, Whitworth Street,* and 4, *St. Werburgh's Road, Chorlton-c.-Hardy, Manchester.*

Date of Election.

1906, April 10. Thewlis, Councillor J. H. *Daisy Mount, Victoria Park, Manchester.*

1911, Oct. 17. Thoday, D., M.A., Lecturer in Plant Physiology in the University of Manchester. *The University, Manchester.*

1911, Jan. 10. Thomson, J. Stuart, Ph.D. (Bern), Senior Demonstrator in Zoology in the Victoria University of Manchester. *The University, 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.*

1911, Oct. 3. Todd, T. Wingate, M.B., Ch.B., Demonstrator in Anatomy in the University of Manchester. *The University, Manchester.*

1899, Oct. 17. Todd, William Henry. *Rivington, Irlam Road, Flixton, near Manchester.*

1909, Jan. 26. Varley, George Percy, M.Sc. (Vic.), Assistant Master in the Municipal Secondary School, Manchester. 18, *Victoria Road, Whalley Range, Manchester.*

1912. Oct. 15. Walker, Miles, M.A , M.I.E.E., Professor of Electrical Engineering, the Municipal School of Technology, Manchester. *The Cottage, Leicester Road, Hale, Altrincham.*

1873, Nov. 18. Waters, Arthur William, F.L.S., F.G.S. *Alderley, McKinley Road, Bournemouth.*

1906, Nov. 13. Watson, D. M. S., M.Sc. 60, *Lissenden Mansions, Highgate Road, London, N.W.*

1892, Nov. 15. Weiss, F. Ernest, D.Sc., F.L.S., Professor of Botany in the Victoria University of Manchester. 30, *Brunswick Road, Withington, Manchester.*

1909, Feb. 9. Weizmann, Charles, Ph.D., D.Sc., Senior Lecturer in Chemistry in the University of Manchester. *The University, Manchester.*

1908, May 12. Welldon, Rt. Rev. J. E. C., D.D., Dean of Manchester *The Deanery, Manchester.*

Date of Election.

1911, Oct. 17. West, Tom, B.Sc., Chemist and Metallurgist. *101, Spring Bank Street, Stalybridge, near Manchester.*

1901, Oct. 1. Wild, Robert B., M.D., M.Sc., F.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.*

1907, Oct. 15. Winstanley, George H., F.G.S., M.I.M.E., Lecturer in Mining Engineering and Mine Surveying in the University of Manchester. *Wigshaw Grange, Culcheth, near Warrington.*

1909, Jan. 26. Wolfenden, John Henry, B.Sc. (Lond.), A.R.C.S. (Lond.), Assistant Master in the Municipal Secondary School, Manchester. 13, *Pole Lane, Failsworth.*

1912, Jan. 23. Wolff, Charles Ernest, M.Sc., A.M.Inst.C.E., Consulting Engineer. *The Clough, Hale, Cheshire.*

1905, Oct. 31. Woodall, Herbert J., A.R.C.S. 32, *Market Place, Stockport.*

1860, April 17. Woolley, George Stephen. *Victoria Bridge, Manchester.*

1863, Nov. 17. Worthington, Samuel Barton, M.Inst.C.E., M.I.Mech.E. *Mill Bank, Bowdon,* and 37, *Princess Street, Manchester.*

1895, Jan. 8. Worthington, Wm. Barton, B.Sc., M.Inst.C.E. *Kirkstyles, Duffield, near Derby.*

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., M.I.Mech.E.

Ingleby, Joseph, M.I.Mech.E.

Johnson, William H., B.Sc.

Worthington, Wm. Barton, B.Sc., M.Inst.C.E.

HONORARY MEMBERS.

Date of Election.	
1892, April 26.	Abney, Sir William de W., K.C.B., D.C.L., D.Sc., F.R.S. *Rathmore Lodge, Bolton Gardens South, South Kensington, London, S.W.*
1892, April 26.	Amagat, É. H., For. Mem. R.S., 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 in the University of Berlin. *Universität, Berlin.*
1889, April 30.	Avebury, Right. Hon. 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 in the University of Munich. 1, *Arcisstrasse, Munich.*
1886, Feb. 9.	Baker, John Gilbert, F.R.S., F.L.S. 3, *Cumberland Road, Kew.*
1889, April 30.	Carruthers, William, F.R.S., F.L.S. 44, *Central Hill, 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 Experimental Philosophy in the University of Oxford. 3, *Bardwell Road, Banbury Road, Oxford.*
1892, April 26.	Curtius, Theodor, Professor of Chemistry in the University of Kiel. *Universität, Kiel.*
1892, April 26.	Darboux, J. Gaston, Membre de l'Institut, Secrétaire perpétuel de l'Académie des Sciences, Doyen honoraire de la Faculté des Sciences. 3, *Rue Mazarine, Paris.*

Date of Election.

1894, April 17. Debus, H., Ph.D., F.R.S. 4. *Schlangenweg, Cassel, Hessen, Germany.*

1900, April 24. Dewar, Sir James, M.A., LL.D., D.Sc., F.R.S., V.P.C.S., Fullerian Professor of Chemistry at the Royal Institution. *Royal Institution, Albemarle Street, London, W.*

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, Sir J. Alfred, K.C.B., M.A., LL.D., F.R.S. Director of Naval Education to the Admiralty. *Frog-hole, Edenbridge, Kent.*

1889, April 30. Farlow, W. G., Professor of Botany at Harvard College. *Harvard College, Cambridge, Mass., U.S.A.*

1900, April 24. Forsyth, Andrew Russell, M.A., Sc.D., LL.D., F.R.S., formerly Sadlerian Professor of Pure Mathematics in the University of Cambridge. *Trinity College, Cambridge.*

1892, April 26. Fürbringer, Max, Professor of Anatomy in the University of Heidelberg. *Universität, Heidelberg.*

1900, April 24. Geikie, James, D.C.L., LL.D., F.R.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. *Kilmorie, Colinton Road, Edinburgh.*

1895, April 30. Geitel, Hans. 6, *Lessingstrasse, Wolfenbüttel.*

1894, April 17. Glaisher, J. W. L., Sc.D., F.R.S. *Trinity College, Cambridge.*

1894, April 17. Gouy, A., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Physics in the University of Lyons. *Faculté des Sciences, Lyons.*

1900, April 24. Haeckel, Ernst, Ph.D., Professor of Zoology in the University of Jena. *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, Ph.D., F.R.S. *Homefield, Lower Warberry, Torquay.*

1892, April 26. Hill, G. W. *West Nyack, N.Y., U.S.A.*

Date of Election.

1888, April 17. Hittorf, Johann Wilhelm, Professor of Physics at Münster *Polytechnicum, Münster.*

1892, April 26. Klein, Felix, Ph.D., For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Mathematics in the University of Göttingen. 3, *Wilhelm Weber Strasse, Göttingen.*

1894, April 17. Königsberger, Leo, Professor of Mathematics in the University of Heidelberg. *Universität, Heidelberg.*

1902, May 13. Larmor, Sir 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 in the University of Berlin. 29, *Matthäi-Kirch Strasse, Berlin.*

1887, April 19. Lockyer, Sir J. Norman, K.C.B., LL.D., Sc.D., 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, For. Mem. R.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Professor of Physics in the Universities Leyden and Haarlem. *Zijlweg*, 76, *Haarlem.*

1892, April 26. Marshall, Alfred, M.A., formerly Professor of Political Economy in the University of Cambridge. *Balliol Croft, Madingley Road, Cambridge.*

1901, April 23. Metschnikoff, 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 in the University of Stockholm. *Djursholm, Stockholm.*

1894, April 17. Murray, Sir John, K.C.B., LL.D., Sc.D., Ph.D., F.R.S, F.L.S. *Challenger Lodge, Wardie, Edinburgh.*

1910, April 5. Nernst, Geh. Prof. Dr. Walter, Director of the Physikal-Chemisches Institut in the University of Berlin. *Am Karlsbad 26a, Berlin W. 35.*

Date of Election.

1902, May 13. Osborn, Henry Fairfield, Professor of Vertebrate Palæontology at Columbia College. *Columbia College, New York, U.S.A.*

1894, April 17. Ostwald, W., Professor of Chemistry. *Grossbothen, Kgr. Sachsen.*

1899, April 25. Palgrave, Sir Robert H. Inglis, F.R.S., F.S.S. *Henstead Hall, Wrentham, Suffolk.*

1894, April 17. Pfeffer, Wilhelm, For. Mem. R.S., Professor of Botany in the University of Leipsic. *Botanisches Institut, Leipsic.*

1892, April 26. Quincke, G. H., For. Mem. R.S., Professor of Physics in the University of Heidelberg. *Universität, Heidelberg.*

1899, April 25. Ramsay, Sir William, K.C.B., Ph.D., Sc.D., M.D., F.R.S., Professor of Chemistry in University College, London. 19, *Chester Terrace, Regent's Park, London, N.W.*

1886, Feb. 9. Rayleigh, Right Hon. John William Strutt, Lord, O.M., M.A., D.C.L. (Oxon.), Sc.D. (Cantab.), LL.D. (Univ. McGill), F.R.S., F.R.A.S., Corr. Memb. Inst. Fr. (Acad. Sci.), Chancellor of the University of Cambridge. *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, Right Hon. Sir Henry Enfield, B.A., D.C.L., LL.D., F.R.S., V.P.C.S., Corr. Memb. Inst. Fr. (Acad. Sci.). 10, *Bramham Gardens, Earl's Court, London, S.W.*

1902, May 13. Scott, Dukinfield Henry, M.A., LL.D., Ph.D., F.R.S., F.L.S. *East Oakley House, Oakley, Hants.*

1892, April 26. Solms, H., Graf zu, Professor of Botany in the University of Strassburg. *Universität, Strassburg.*

Date of Election.

1886, Feb. 9. Strasburger, Eduard, D.C.L., For. Mem. R.S., Professor of Botany in the University of Bonn. *Universität, Bonn.*

1895, April 30. Suess, Eduard, Ph.D., For. Mem. R.S., For. Assoc. Inst. Fr. (Acad. Sci.), Professor of Geology in the University of Vienna. 9, *Africanergasse, Vienna.*

1892, April 26. Thiselton-Dyer, Sir William T., K.C.M.G., C.I.E., M.A., Sc.D., Ph.D., LL.D., F.R.S. Lately Director Royal Botanic Gardens, Kew. *The Ferns, Witcombe, Gloucester.*

1895, April 30. Thomson, Sir Joseph John, O.M., M.A., Sc.D., F.R.S., Cavendish Professor of Experimental Physics in the University of Cambridge. *Trinity College, Cambridge.*

1894, April 17. Thorpe, Sir T. Edward, C.B., Ph.D., D.Sc., LL.D., F.R.S., V.P.C.S. *Whinfield, Salcombe, S. Devon.*

1894, April 17. Turner, Sir William, K.C.B., M.B., D.C.L., LL.D., Sc.D., F.R.S., F.R.S.E., Professor of Anatomy in the University of Edinburgh. 6, *Eton Terrace, Edinburgh.*

1886, Feb. 9. Tylor, Sir Edward Burnett, D.C.L. (Oxon), LL.D. (St. And. and McGill Univs.), F.R.S., formerly Professor of Anthropology in the University of Oxford. *Linden, Wellington, Somerset.*

1894, April 17. Vines, Sidney Howard, M.A., D.Sc., F.R.S., F.L.S., Sherardian Professor of Botany in the University of Oxford. *Headington Hill, Oxford.*

1894, April 17. Warburg, Emil, Professor of Physics at the Physical Institute, Berlin. *Physikalisches Institut, Neue Wilhelmstrasse, Berlin.*

1894, April 17. Weismann, August, For. Mem. R.S., Professor of Zoology in the University of Freiburg. *Universität, Freiburg i. Br.*

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.

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 METSCHNIKOFF, 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 pls.*)

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.*)

1905. (Feb. 28.) "The Early History of Seed-bearing Plants, as recorded in the Carboniferous Flora." By Dr. D. H. SCOTT, F.R.S. *(32 pp., 3 pls.)*

1906. (March 20.) "Total Solar Eclipses." By Professor H. H. TURNER, D.Sc., F.R.S. *(32 pp.)*

1907. (February 18.) "The Structure of Metals." By Dr. J. A. EWING, F.R.S., M.Inst.C.E. *(20 pp., 5 pls., and 5 text-figs.)*

1908. (March 3.) "On the Physical Aspect of the Atomic Theory." By Professor J. LARMOR, Sec. R.S. *(54 pp.)*

1909. (March 9.) "On the Influence of Moisture on Chemical Change in Gases." By Dr. H BRERETON BAKER, F.R.S. *(8 pp.)*

1910. (March 22.) "Recent Contributions to Theories regarding the Internal Structure of the Earth." By Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S.

LIST OF PRESIDENTS OF THE SOCIETY.

Date of Election.	
1781.	Peter Mainwaring, M.D., James Massey.
1782-1786.	James Massey, Thomas Percival, M.D., F.R.S.
1787-1789.	James Massey.
1789-1804.	Thomas Percival, M.D., F.R.S.
1805-1806.	Rev. George Walker, F.R.S.
1807-1809.	Thomas Henry, F.R.S.
1809.	*John Hull, M.D., F.L.S.
1809-1816.	Thomas Henry, F.R.S.
1816-1844.	John Dalton, D.C.L., F.R.S.
1844-1847.	Edward Holme, M.D., F.L.S.
1848-1850.	Eaton Hodgkinson, F.R.S., F.G.S.
1851-1854.	John Moore, F.L.S.
1855-1859.	Sir William Fairbairn, Bart., LL.D., F.R.S.
1860-1861.	James Prescott Joule, D.C.L., F.R.S.
1862-1863.	Edward William Binney, F.R.S., F.G.S.
1864-1865.	Robert Angus Smith, Ph.D., F.R.S.
1866-1867.	Edward Schunck, Ph.D., F.R.S.
1868-1869.	James Prescott Joule, D.C.L., F.R.S.
1870-1871.	Edward William Binney, F.R.S., F.G.S.
1872-1873.	James Prescott Joule, D.C.L., F.R.S.
1874-1875.	Edward Schunck, Ph.D., F.R.S.
1876-1877.	Edward William Binney, F.R.S., F.G.S.
1878-1879.	James Prescott Joule, D.C.L., F.R.S.
1880-1881.	Edward William Binney, F.R.S., F.G.S.
1882-1883.	Sir Henry Enfield Roscoe, D.C.L., F.R.S.
1884-1885.	William Crawford Williamson, LL.D., F.R.S.
1886.	Robert Dukinfield Darbishire, B.A., F.G.S.
1887.	Balfour Stewart, LL.D., F.R.S.

* Elected April 28th; resigned office May 5th.

Date of Election.	
1888-1889.	Osborne Reynolds, LL.D., F.R.S.
1890-1891.	Edward Schunck, Ph.D., F.R.S.
1892-1893.	Arthur Schuster, Ph.D., F.R.S.
1894-1896.	Henry Wilde, D.C.L., F.R.S.
1896.	Edward Schunck, Ph.D., F.R.S.
1897-1899.	James Cosmo Melvill, M.A., F.L.S.
1899-1901.	Horace Lamb, M.A., F.R.S.
1901-1903.	Charles Bailey, M.Sc., F.L.S.
1903-1905.	W. Boyd Dawkins, M.A., D.Sc., F.R.S.
1905-1907.	Sir William H. Bailey, M.I.Mech.E.
1907-1909.	Harold Baily Dixon, M.A., F.R.S.
1909-1911.	Francis Jones, M.Sc., F.R.S.E.
1911-	F. E. Weiss, D.Sc., F.L.S

Vol. 56: Part I.

MEMOIRS AND PROCEEDINGS
OF
THE MANCHESTER LITERARY & PHILOSOPHICAL SOCIETY, 1911-1912.

CONTENTS.

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Price Five Shillings and Sixpence.

April 29th, 1912.

RECENT ADDITIONS TO THE LIBRARY

Presented.

Green (J. A.). A Biographical Guide to the Gaskell Collection in the Moss Side Library. Manchester, 1911. (*Recd. 1/xii./11.*)

London.—British Museum. (Natural History.) Guide to the Exhibition of Animals, Plants, and Minerals mentioned in the Bible. London, 1911. (*Recd. 14/xi./11.*)

——.— —— Guide to Mr. Worthington Smith's Drawings of Field and Cultivated Mushrooms and Poisonous or Worthless Fungi often Mistaken for Mushrooms. London, 1910. (*Recd. 14/xi./11.*)

——.— **Patent Office.** Subject List of Works on Chemistry . . . . in the Library of the Patent Office. (New Series, ZC—ZQ.) London, 1911. (*Recd. 31/x./11.*)

——.— —— Subject List of Works on Chemical Technology . . . . in the Library of the Patent Office. (New Series, YN—ZB.) London, 1911. (*Recd. 19/xii./11.*)

——.— —— Subject List of Works on Peat, Destructive Distillation, &c., ... in the Library of the Patent Office. (New Series, YK—YM.) London, 1911. (*Recd. 19/xii./11.*)

——.—**Royal Society.** Catalogue of a Collection of Early Printed Books in the Library of the Royal Society. By H. M. Mayhew and R. F. Sharpe. London, 1910. (*Recd. 1/xii./11.*)

Madison—Wisconsin History Commission.—Bibliography of Wisconsin in the War. By I. S. Bradley, n.p., 1911. (*Recd. 18/i./12.*)

Manchester and London.—The Medical Chronicle. Vol. iv. (1886)—vi. (1887); New Series, Vol. i. (1894)—x. (1899); 3rd Series, Vol. i. (1899)—iv. (1901); 4th Series, Vol. i. (1901)—xxii. (No. 3, Dec., 1911). Manchester and London. (*Recd. 20/ii./12.*)

Marsden (V. E.) The Revolution in Finland under Prince John Obolensky. By V. Vladimirov. Trans. from the Russian by V. E. Marsden. London, 1911. (*Recd. 1/xii./11.*)

New York.—Pennsylvania Society. Report on William Penn Memorial in London: erected by the Pennsylvania Society in the City of New York, July, MCMXI. By Barr Ferree, Secretary of the Society. New York, 1911. (*Recd. 4/i./12.*)

VOL. 56: PART II.

MEMOIRS AND PROCEEDINGS

OF

THE MANCHESTER LITERARY & PHILOSOPHICAL SOCIETY, 1911-1912.

CONTENTS

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Barcelona.—Institut d' Estudis Catalans. Arxius de l'Institut de Ciencies. Any I., No. 1. Barcelona, n.d. (*Recd. 29/iv./12.*)

Buchanan (J. Y.). In and Around the Morteratsch Glacier: A Study in the Natural History of Ice. *The Scottish Geographical Magazine*, April, 1912. (*Recd. 1/vii./12.*)

Marsden (V. E.). Russia's Policy in Finland. By G. Evreinov. Trans. from the Russian by V. E. Marsden. London, 1912. (*Recd. 17/v./12.*)

Naples—Società Reale di Napoli. Memorie della Reale Accademia di Archeologia, Lettere e Belle Arti. Vol. I. Napoli, 1911. (*Recd. 28/iv./12.*)

Russell (H. C.). [A Collection of twenty-seven Papers, by H. C. Russell.] (*Recd. 25/vi./12.*)

Sarawak.—The Sarawak Museum Journal. Vol. I., No. 1. Sarawak, 1911. (*Recd. 7/vi./12.*)

——. The Ninth Report of the Sarawak Museum, 1910. By J. C. Moulton. Sarawak, n.d. (*Recd. 7/vi./12.*)

Sendai.—Tôhoku Imperial University. The Science Reports of the Tôhoku Imperial University of Sendai, Japan. Vol. I—. Sendai, 1912. (*Recd. 10/v./12.*)

——.— —— The Tôhoku Mathematical Journal. Vol. I—. Sendai, 1911. (*Recd. 10/v./12.*)

Sydney.—Results of Meteorological Observations made in New South Wales during 1887; 1888; 1889; 1890; 1898; 1899; and 1900, 1901, and 1902; under the direction of H. C. Russell. 7 vols. Sydney, 1889—1904. (*Recd. 25/vi./12.*)

——.— Results of Rain, River, and Evaporation Observations made in New South Wales during 1888; 1889; 1890; 1891; 1892; 1893; 1894; 1895; 1896; 1897; 1898; 1899; 1900; 1901-1902; under the direction of H. C. Russell. 14 vols. Sydney, 1889-1904. (*Recd. 25/vi./12.*)

Taihoku.—Bureau of Productive Industries, Government of Formosa. Incones Plantarum Formosanarum, nec non et Contributiones ad Floram Formosanam. Fasc. I. Taihoku, 1911. (*Recd. 24/v./12.*)

Vol. 56: Part III.

MEMOIRS AND PROCEEDINGS

OF

THE MANCHESTER LITERARY & PHILOSOPHICAL SOCIETY, 1911-1912.

CONTENTS.

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RECENT ADDITIONS TO THE LIBRARY.

Presented.

Batavia.—Bataviaasch Genootschap van Kunsten en Wetenschappen. Rapporten van de Commissie in Nederlandsch-Indië voor Oudheidkundig Onderzoek op Java en Madoera. 1909 and 1910. Batavia, &c., 1911. (*Recd. 9/ix./12.*)

——.— **Koninklijk Magnetisch en Meteorologisch Observatorium te Batavia.** Die Wind-verhältnisse in den oberen Luftschichten nach Ballonvisierungen in Batavia. Von Dr. W. van Bemmelen. Batavia, 1911. (*Recd. 9/ix./12.*)

——.— —— I. Drachen- und Fesselballon-beobachtungen. II. Wissenschaftliche Ergebnisse der Aufstiege mit dem Freiballone "Batavia." Von Dr. C. Braak. Batavia, 1912. (*Recd. 9/ix./12.*)

Chicago.—Newberry Library. The Arabic and Turkish Manuscripts in the Newberry Library. By D. B. Macdonald. Chicago, Ill., 1912. (*Recd. 7/ix./12.*)

Christiania.—Observatorium. Meridian-Beobachtungen von Sternen in der Zone 65°—70° nördlicher Declination. II. Katalog für das Aequinoctium 1900.0. Von H. Geelmuyden und J. Fr. Schroeter. Christiania, 1912. (*Recd. 28/viii./12.*)

Delft.—Technische Hoogeschool. De Temperatuursinvloed op Physiologische Processen der Alcoholgist ...door J. E. van Amstel. Amsterdam, 1912. (*Recd. 7/ix./12.*)

——.— —— Het Aethyleeren van Chloorbenzol. ...door J. G. W. Sieger. Amsterdam, 1912. (*Recd. 7/ix./12.*)

——.— —— Proeve eener Theorie van het Roteerend Magnetisch Veld.... door P. M. Verhoeckx. 's Gravenhage, 1912. (*Recd. 7/ix./12.*)

——.— —— Stranden en Strandverdediging. ...door L. R. Wentholt. [Text and Atlas.] Delft, 1912. (*Recd. 7/ix./12.*)

La Plata.—Direcciòn General de Estadistica de la Provincia de Buenos Aires. Censo General de la Ciudad de La Plata... By C. P. Salas and A. C. Alcorta. La Plata, 1910. (*Recd. 9/ix./12.*)

London.—Patent Office. Subject List of Works on Mineral Industries... in the Library of the Patent Office, Pt. 2. (New Series, XN 40—XR.); Pt. 3 (New Series, XS—YH.). London, 1912. (*Recd. 21/viii./12.*)

London.—Patent Office. Subject List of Works on Horology... in the Library of the Patent Office. (New Series, FO—FR.). (*Recd. 11/ix./12.*)

——.— **Royal Society.** The Record of the Royal Society of London... 3rd Ed. London, 1912. (*Recd. 17/viii./12.*)

——.— —— The Signatures in the First Journal-Book and the Charter-Book of the Royal Society... London, 1912. (*Recd. 17/viii./12.*)

——.— **University College.** Catalogue of the Periodical Publications, including the Serial Publications of Societies and Governments in the Library of the University College, London. By L. Newcombe. Oxford, 1912. (*Recd. 6/ix./12.*)

Sidebottom (Henry). Lagenae of the South-West Pacific Ocean. From soundings taken by H.M.S. *Waterwitch*, 1895. By Henry Sidebottom. London, 1912. (*Recd. 24/vii./12.*)

New Exchange.

London.—Faraday Society. Transactions.

And the usual Exchanges and Periodicals.

Washington.—United States Geological Survey. Geologic Atlas of the United States, Folios Nos. 174—182. Washington, D.C., 1910—1912. (*Recd. 17/vii./12.*)

Purchased.

Alder (J.) and **Hancock (A.)** The British Tunicata. Vol. III. Published by the Ray Society. London, 1912. (*Recd. 19/iii./12.*)

Thiselton-Dyer (Sir W. T.). Flora Capensis. Vol. V., sect. 1, part iv. London, 1912. (*Recd. 27/vi./12.*)

West (W.) and **(G. S.).** A Monograph of the British Desmidiaceae. Vol. IV. Published by the Ray Society. London, 1912. (*Recd. 19/iii./12.*)

New Exchanges.

Sendai.—Tôhoku Imperial University. The Science Reports; and The Tôhoku Mathematical Journal.

Taihoku.—Bureau of Productive Industries. Icones Plantarum Formosanarum, nec non et Contributiones ad Floram Formosanam.

And the usual Exchanges and Periodicals.

Osborn (H. F.). Evolution of Mammalian Molar Teeth. New York, 1907. (*Recd. 22/i./12.*)

——. (**H. F.**). [A Collection of some eighty Papers from various Journals, by H. F. Osborn.] (*Recd. 22/i./12.*)

Sessions (F.). Literary Celebrities of the English Lake-District. London, 1907. (*Recd. 4/iii./12.*)

Stockholm.—Académie Royale Suédoise des Sciences. Les Prix Nobel en 1909. Stockholm, 1910. (*Recd. 19/xii./11.*)

——.— —— Les Prix Nobel en 1910. Stockholm, 1911. (*Recd. 19/xii./12.*)

——.— —— Meridiangradmätning vid Sveriges Västra Kust. By P. G. Rósen. Uppsala and Stockholm, 1911. (*Recd. 19/xii./12.*)

Purchased.

Thiselton-Dyer (Sir **W. T.**). Flora Capensis. Vol. V., Sect. 1, part iii. London, 1911. (*Recd. 17/i./12.*)

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