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NEW SERIES, VOL. VIII., PART I.

Yours very truly

William Ramsay

Professor William Ramsay,

PH.D., F.R.S.

PROFESSOR WILLIAM RAMSAY, Ph.D., F.R.S., was born at Glasgow, Oct. 2, 1852; his grandfather was a manufacturing chemist; his father, William Ramsay, was an engineer, and his mother, Catherine Robertson, was the daughter of Archibald Robertson, M.D., an Edinburgh physician. He married Margaret Buchanan in 1881. The celebrated geologist, Sir Andrew C. Ramsay, was his uncle.

William Ramsay was educated at the Glasgow Academy until his fifteenth year, and at the Glasgow University from 1867 to 1870. He then proceeded to Tübingen and studied chemistry under Professor Fittig until 1872, when he graduated Ph.D. From 1872 to 1874 he acted as Chief Assistant to the "Young" Chair of Technical Chemistry in Anderson's College, Glasgow; and from 1874 to 1880 as "Tutorial" Assistant to the Chemical Professor in Glasgow University. He was appointed Professor of Chemistry in University College, Bristol, in 1880, and Principal of the College in 1881. He was President of the Bristol Naturalists' Society from 1884 to 1887. In the latter year Professor Williamson resigned the Chair of Chemistry in University College, London, and Professor Ramsay was appointed his successor.

Professor Ramsay was elected a Member of the Berlin Chemical Society in 1872, a Fellow of the London Chemical

Society in 1874, a Member of the London Physical Society in 1886, and a Fellow of the Royal Society in 1888; he is one of the original members of the Institute of Chemistry, and of the Society of Chemical Industry. He has served on the Council of the Chemical and Physical Societies, and has been a Vice-President of the Chemical Society and of the Institute of Chemistry. Dr. Ramsay's earliest original work was published in 1872, and for a few years he devoted himself to Organic Chemistry. In 1876, however, he turned his attention to the determination of specific volumes, and devised a new method which has since been frequently used; since then, a large part of his work has been in the domain of Physical Chemistry, and included researches on dissociation, the vapour pressures of liquids and solids, the volatilisation of solids, the thermal properties of three alcohols, ether, acetic acid, and water, some thermodynamical relations, the nature of liquids, the continuity of the gaseous and liquid states of matter, the compressibility of gases under very low pressures, the ratio of the specific heats of gases and vapours through wide ranges of temperature and pressure by a modification of Kundt's method, and the surface energy of liquids from low temperatures up to the critical point by a new method. The last research has led to a method of determining the molecular condition of liquids. Between the years 1882 and 1887, the present President of the Naturalists' Society was associated with Dr. Ramsay in most of his researches.

In 1893 Lord Rayleigh observed that the density of nitrogen obtained from atmospheric air was slightly higher than that of nitrogen obtained from its compounds, and it occurred to Professor Ramsay that some light might be thrown on this remarkable discrepancy by absorbing the atmospheric nitrogen by means of strongly heated magnesium. The result of his experiments was the discovery of a new gaseous constituent of the air, the same gas having also been isolated by Lord Rayleigh at the same time by causing the atmospheric nitrogen to combine with oxygen by the passage of electric sparks. The discovery had been to a certain extent anticipated by Cavendish, who noticed that when atmospheric nitrogen was sparked with oxygen a small residue—rather less then 1 per cent.—was left, but he was unable to ascertain the nature of the substance, and the observation was entirely overlooked until after the researches of Lord Rayleigh and Professor Ramsay had been completed. On account of its inertness the new gas has been named "Argon" by the discoverers. The gas has been liquefied and the boiling-point and critical temperature and pressure of the liquid determined by Olszewski. The remarkable observation has been made by Professor Ramsay that the ratio of the specific heat of argon at constant pressure to that at constant volume possesses almost exactly the theoretical value 1·66 for a monatomic gas, as is also the case with mercury vapour. As the density of argon compared with hydrogen is about 20, it would appear that the atomic weight—if the gas is elementary—must be nearly 40, and a difficulty thus arises in placing the element in the periodic table of the elements. The solution of this problem will be of great theoretical interest.

Shortly after the discovery of argon, Dr. Ramsay was led to examine the gas evolved by treating certain minerals containing uranium, notably cleveite, with sulphuric acid. This gas had been previously obtained by Hillebrand, who considered it to consist of nitrogen. Professor Ramsay found, however, that when an electric discharge is passed through the gas under low pressures, a bright yellow light is emitted, and a spectroscopic examination of the light showed the presence of a yellow line apparently identical in position with the line D_3, noticed in 1868 by Lockyer in the spectrum of the chromosphere. Lockyer attributed this line to the presence of an element then unknown on the earth, and which he termed "helium."

The same gaseous element has now been obtained from several other rare minerals containing uranium, yttrium, and thorium. Professor Ramsay finds that the density of helium compared with hydrogen is about 2·13, and that the ratio of the specific heats has the theoretical value for a monatomic gas; the atomic weight therefore appears to be about 4, and we have therefore now an element between hydrogen (atomic weight=1) and lithium (atomic weight=7). Helium, like argon, is characterised by its remarkable inertness. The value of Professor Ramsay's researches, chiefly those on argon and helium which have excited the greatest interest, has been widely recognised both in this country and abroad, and he has been elected a corresponding member of the Institute of France (Académie des Sciences), and a Foreign Member of the "Société Hollandaise des Sciences" (Leyden), of the "Société d'Histoire Naturelle" of Geneva, and of the Bohemian Academy of Sciences. He has also received the Barnard Medal of the Colombia College, New York, awarded by the American Academy of Sciences; the Davy Medal of the Royal Society; the Leblanc Medal of the French Chemical Society, and jointly with Lord Rayleigh he has received the Hodgkins Prize of $10,000 awarded by the Smithsonian Institute, Washington, and a prize of 25,000 francs awarded by the French Academy. Professor Ramsay is the author of several well-known text-books of chemistry.

Professor Ramsay has read the following papers at meetings of the Bristol Naturalists' Society :—

1. "On the Connection between Chemical Composition and Physiological Action"; read February 5th, 1881.

2. "On Water"; read April 5th, 1883.

3. "On Ice, Water, and Steam"; read December 6th, 1883. Dr. S. Young was joint author of this paper.

4. "On the Volcanic Phenomena in the U.S. National Park on the Yellowstone River"; read March 6th, 1884.

5. "The Rigidity of Chains"; read January 11th, 1886.

6. "The Critical Point of Fluids"; read March 11th, 1886.

Summer Visitors to the Neighbourhood of Bristol.

By H. C. PLAYNE, M.A. Oxon.

THE paper which I am going to read to-night is, I am afraid, not very scientific, but only some rather rambling words about a few of the small birds which come to this neighbourhood to spend the summer. These small creatures, as you probably know already, come some thousands of miles from the countries in which they have spent the winter, and yet they manage to arrive with almost unfailing regularity by routes and methods about which only little is as yet known. I will ask you, then, to imagine that it is towards the end of March, when the weather is already warmer, and the Leigh Woods and slopes of the Downs are full of the songs of the hardier birds who have spent the winter with us. The chaffinch, who has been practising his song so diligently all through February, has now reached perfection, and is producing that unvarying strain of his at the rate of six or seven times a minute.

At this time the robin is so deceptive that, as we walk along the Downs, he continually makes us imagine we have heard a redstart or a blackcap a fortnight before he is due. Whether the deception on the part of the robin is intentional or not, I am unable to say.

We will not stay on the Downs, but will go to a likely spot to see the first arrival of the visitors. Suppose we go to Combe Dingle, for that always seems the place where they are to be seen first. If in our eagerness we have not gone too early, we shall presently see a small olive-green bird flitting along from bush to bush, searching for insects in the leaves, and at times catching one in the air. Perhaps farther up the valley we may see another, behaving in the same way and making no sound. There is no doubt about it, the chiffchaff has come, and spring has begun at last.

I feel convinced myself that the first arrivals of many of the warblers reach this neighbourhood by coming down the Severn Valley, and not in the opposite direction as might be expected. Very possibly parties of migrants travelling directly northwards from the south coast may arrive here later, but the first to come are travelling down the Severn Valley; where they enter the valley I do not know. Last spring a chiffchaff was seen in Combe Dingle on March 16th, and on March 19th I saw one in the same spot; he was not moving on at all, nor making any sound, and I am inclined to think he may have been there all the winter. On the 23rd, in the Penpole fields I saw two chiffchaffs; one was calling, but a strong wind made it difficult to hear. At this time I believe there were none in the Leigh Woods. On March 26th I had a most delightful experience; with a friend, Mr. D. T. Price, I went out to Pilning in the flat fields by the Severn to see if we could detect any migratory movement, and we spent the afternoon watching chiffchaffs steadily moving on down the valley. They came steadily, by short flights, following the hedges, singly and in parties of two or three, some silent and some continually calling. Now and then, when the sun shone brightly, one would break into song. They could not be persuaded to go in the opposite direction, and flew round us if we stood in their way. There was no doubt that we were watching a large army of chiffchaffs. Very soon the Leigh Woods and Downs were full of these little birds, and each spot where one had sung the year before seemed to be occupied again. How is it that these small creatures, after making two such enormous journeys, yet manage to arrive with such regularity often in the exact spot at which they spent the previous summer?

There are two near relations of the chiffchaff which arrive rather later, but it is interesting to compare the three. These two cousins of the chiffchaff are the willow wren and wood wren; each of the three is called *Phylloscopus*, because they search the leaves for their food. In many respects they are much alike, and so long as they are silent it is almost impossible to distinguish between the chiffchaff and willow wren when they are flitting about the trees before you. But there is no such difficulty when they are singing, for the jerky two notes uttered almost incessantly by the chiffchaff from the moment of his arrival are not at all like the sweet little song of the willow wren. Their call notes are more alike, but a little practice soon enables one to distinguish between them.

Each builds a small, oval-shaped nest, domed, with the entrance at the side; but while the willow wren's is on the ground, the chiffchaff's is generally a little above it. A favourite site for the chiffchaff's nest is the edge of a straggling bramble bush, where it can be well hidden by the tall grasses which grow round it.

But my favourite of the three is the wood wren, abundant in the Leigh Woods, especially Nightingale Valley, but not on the Downs. He is rather larger than his cousins, and is yellower on the upper parts, whiter on the under.

His song is rather like an audible shiver, which begins slowly and then seems to get hold of the bird so that he cannot stop himself. The call note is a most beautiful sound, and you can hear it to perfection if you go to the Leigh Woods at the end of May when the hen is sitting on the nest, and walk about under the trees in which the cock bird is singing. He is soon very anxious, and instead of the song you will hear a long plaintive note which is so full of anxiety that you cannot help feeling sorry for being the cause of it. If you go too near the nest, the hen will slip off it very likely without being seen, and you will know that she has done so by hearing two birds crying in the trees instead of one. To find the nest you must sit down quietly a little way off and watch; it requires careful watching, for the hen has a habit of suddenly dropping to the nest from some height above the ground, and if she succeeds in escaping your notice when doing this, all must begin again.

The nest is generally in a slight hollow in a bank, sometimes wonderfully hidden, like the willow wren's, but with one peculiar difference. The chiffchaff and willow wren invariably line their nests with feathers, whereas the wood wren uses no feathers at all. For some reason or other wood wrens dislike feathers, or perhaps they are not so far advanced as their cousins and have not yet discovered that feathers are of use for nest-building. I shall always remember one afternoon in that oak glade in Shirehampton Park some years ago, when I watched a cock wood wren feeding his hen as she sat on the nest. How he hovered in the air above the nest and quickly darted down to it and up again is more than I can describe. You are not likely to meet any other member of this family near here at present, but if you go to the Alps you will find a little bird rather like our wood wren abundant on the mountain slopes where there are trees. This is Bonelli's warbler, and it is well to pay especial attention to him, because he is supposed to be extending his range northwards, and may perhaps reach England before long. I myself saw him near Luçon in France a year and a half ago. When I was hearing him continually near Meiringen more than two years ago, he always seemed to have his shivering song under control, and not to be carried away by it like the wood wren.

There is one more sight of birds on migration which can always be seen here in the spring, and that is the arrival of the wheatears on the Downs. They do not come to stay, but only rest a few hours on their way to breeding grounds on other hills and moors. Very soon after the chiffchaff has come, if you go up on the Downs in the morning you will see large parties of wheatears—running rapidly over the ground one moment, then flying and showing that white in the tail as they go, then perching on a stone and becoming almost invisible. By means of telegrams one year I discovered that they arrive on Minchinhampton Common (about thirty miles from here in a N.E. direction) before they arrive on the Downs. A few pairs breed at Minchinhampton, and there is a custom there—when it began I do not know—connected with the arrival: the owner of the quarries gives his workmen beer on the day on which the wheatears are first seen. Consequently the quarrymen are rather keen in watching for their arrival.

By the end of April the slopes of the Downs are quite crowded with numbers of visitors, who have come to nest again where they spent the previous summer. And yet they are not received hospitably; a week's careful work is ruthlessly destroyed in a moment as a nest is pulled out only to be thrown down beside the path. Any one who is in the habit of watching the birds on the Downs cannot but be struck by the number of nests that are destroyed. The birds learn, at any rate, to be skilful in hiding their nests, and bold in sitting quiet on them. Last summer I much admired a blackcap who sat steadily on the nest in a small bramble bush only a short distance above the ground, while several small boys were picking flowers all round, making their usual noise, and even kicking against the bush. The cock blackcap often takes his turn on the nest, but always seems more ready to leave it than the hen. Once last summer when I put the cock off the nest he broke out into loud song—perhaps in anger, or perhaps in pleasure at being relieved from an unpleasant duty, for he did not go back, and I saw the hen take his place. That birds do sing from anger is, I feel sure, the case at times. Sedge warblers will often be roused to song if a stone be thrown into the bush where they are, and I have heard a nightingale sing more vehemently than before while I was looking at his nest from which I had just flushed his wife.

There are nightingales on the Downs, and more of them than you would think, for they seem rather more silent than they are in other places, and it is difficult to find them in good song. But they nest on the Downs, and their nests are wonderfully concealed and often exceedingly difficult to find—generally among a thick jungle of bushes, and so deep in the ground ivy that you cannot see them till your eyes are just over them. I saw two nests last summer on the Downs quite close to a road, in both of which the young were successfully reared. One day I crawled up to one until my head was almost touching the hen as she sat on the nest. At last she fluttered away along the ground, leaving her young just hatched; she did not go far, but waited till I had retired, and then returned again; and presently I heard a loud churr, and saw the cock come and perch on a branch above the nest, with a green caterpillar in his bill. Young nightingales in a nest are a good instance of protective colouring, for I have known it quite hard to distinguish them from a small heap of dead leaves.

Let us now leave the Leigh Woods and Downs, and make a small expedition to Cadbury Camp, or rather that long ridge which stretches from the camp to Clevedon. It is covered with gorse and bracken and small bramble bushes. A line of telegraph wires, which are always favourite perching places of birds, runs along the top. As soon as we arrive we shall see the tree pipit perched there, and shall be able to watch him as he keeps rising quickly high in the air, and then slowly falling back to his perch with wings raised and tail spread, uttering those delightful long notes as he descends. His nest is a little way down the bank, snugly sheltered by the bracken, but we may watch long before the bird will help us find it. The gorse on the top of the hill and the trees half-way down are full of birds, some visitors and some residents; but we have come to see one particular visitor. Before we have walked very far, especially if we are there towards evening, we shall probably hear a curious noise somewhat like that of a grasshopper, or perhaps more like the noise made by the reel of a fishing rod. It is continuous for several seconds at a time, and even minutes, and it is difficult to decide from which direction it comes. At last we shall discover a small brown bird with a curiously shaped tail perched on the top of a gorse bush not far from us, reeling with all his might. While we are watching him, he will dive down into the bush, and slip about through the thick branches like a mouse till he is out of sight. It is the grasshopper warbler, not by any means a common bird, though sometimes fairly abundant in suitable localities. He seems equally happy among the gorse of a dry place like Cadbury Camp and among the thick rough grass of a damp osier bed. To find the nest is a puzzle indeed, and you may spend many hours searching, as I have done, without success. However, I have seen two nests which I helped to find—one near Oxford, and the other at Cadbury Camp the summer before last. It was on May 19th that I went with Mr. D. T. Price to look for the nest, and after a long search for more than an hour, Mr. Price saw a small bird flutter away at his feet, and then we found the nest deep down in a tuft of grass close to bramble and gorse bushes,—so deep down that you could not possibly see it unless you moved the grass away with your hand. The nest was made almost entirely of wide blades of dry grass, with one or two leaves woven on the outside. It contained six eggs, which were hatched three days later. When I visited the nest again, the hen slipped off in the orthodox manner described in books. When we stood by the nest we saw no bird, but noticed the grass shaking as though some small creature were moving under it; presently this movement reached a little path bare of grass, and then a small head appeared from the grass on one side of the path, looked up and down it, and a small body ran across like a mouse and disappeared in the grass on the other side. That was absolutely all that was seen of the bird. Each of the nests I have seen was found in the same way,—that is, by seeing the bird fly off it,—but though I paid several visits afterwards, I never saw the hen fly off again, but she always slipped away under cover and kept quite silent. There were grasshopper warblers at Cadbury Camp again last summer, but many hours were spent by friends and myself in vain search for a nest.

Before leaving Cadbury Camp we will walk quietly to a bare rock among the gorse, for there a nightjar was in the habit of spending the day all last summer. One day he was good enough not only to let me come quite close and look at him, but even allowed me to bring some friends, one by one, to see him too. His beautifully marked plumage harmonized so well with the rock that it was quite difficult to point him out, but he lay there blinking his eyes and did not seem to mind a considerable amount of pointing and talking, and only flew away when we were really too impertinent, and tried to attract the attention of some friends who were some way off.

Let us now make an expedition in quite another direction, and pay a visit to three members of one family who are not very distantly related to the grasshopper warbler. These three are members of the family *Acrocephalus*, and are all to be found close together on the banks of the Avon between Bristol and Bath. They are the sedge warbler, reed warbler, and marsh warbler. The first of the three is generally very abundant in suitable ground, that is in osier beds or hedges and bushes, as a rule not far from water of some sort, though there need not be much of it. He is an indefatigable singer, and his harsh but cheerful song can often be heard by night as well as by day. He is something of a mimic, too, but not to be mentioned with his cousin the marsh warbler in that respect. You will be able to find plenty of his nests in all kinds of plants and bushes, and the bird is easy to see, though he is so restless. The reed warbler is not so obtrusive as the sedge warbler; he is much quieter and more restrained; his song is much sweeter and more gentle, though similar in many ways to that of the sedge warbler. A glance at the birds will enable you to distinguish between them at once, for the sedge warbler has a very distinct light stripe just above the eye, which is too faint in the reed warbler to be noticed.

The reed warbler sometimes suspends his nest from reed stems over the water, but quite as often places it in bushes or osiers. I am afraid I have already said something about the marsh warbler here; but if you will allow me I should like to mention him again, because it would not be right to omit the most interesting of the three cousins. In the osier bed to which I would take you, there are plenty of sedge warblers and reed warblers; but if you should chance to be there fairly early in the morning in the latter half of June, I think you would soon notice another voice at times somewhat like the voices of the other two, but more often quite different from them. You may perhaps see the singer perched on a tall piece of meadow-sweet,or moving about on the osier stems, more restless than the reed warbler, yet with plumage almost exactly the same. It is really almost impossible to distinguish between skins of the two birds; but you will not for long have any doubt about the difference between them if you sit down and listen for half an hour. If you are familiar with the songs of the commoner birds, you are likely to hear a performance you would hardly have believed possible. He imitates them one after another—chaffinch, thrush, partridge, tree pipit, great tit, swallow, willow wren, whitethroat, and many others. There is no mistaking the spirit in which he does it. At times he will sing a song of his own not very unlike the reed warbler's, and then suddenly you could be certain that a tree pipit is singing in the little clump of meadow-sweet in front of you, were it not obviously impossible.

In addition to the song, the nest and egg of the marsh warbler are easily distinguished from those of the reed warbler. The marsh warbler does not place his nest over water, but among the rank herbage that grows in damp places. Meadow-sweet is the favourite plant, though osiers and other plants are sometimes made use of. Again there is another difference which was first noticed by Mr. Warde Fowler, and that is that the stems which support the marsh warbler's nest pass outside the nest and are fastened to it only at the rim, while those which support a reed warbler's nest generally are built into the walls of the nest from near the bottom to the top.

A few years ago it was denied that the marsh warbler visited this country, and for some time, owing to his resemblance when dead to the reed warbler, he was overlooked. He is probably much more abundant than is thought, but easily passed over. For the last two years he has nested between Bristol and Bath. In 1894 I found a nest on June 19th, and the young hatched on July 5th, and this year I heard the cock singing on June 6th, and Mr. A. F. R. Wollaston found the nest on June 20th. Unfortunately, when we went to visit it again, expecting to find the young hatched, we found the nest pulled out and lying on the ground.

It is now time to bring my very rambling paper to a close. I have confined myself to very few of the number of species which come here as summer visitors. There are many others quite as numerous and quite as interesting as those I have mentioned, but it was necessary to make a selection out of so many, and naturally I have selected my own favourites.

Notes on the British Jurassic Brachiopoda.

PART I.

BY J. W. D. MARSHALL.

BEFORE we proceed to the consideration of the Brachiopoda found in the Jurassic rocks of this country, I purpose making a few general remarks on the Brachiopoda as a class.*

This course will probably help to make clearer some of the points to which I shall presently direct your attention.

In these preliminary observations, however, I shall, as far as possible, avoid dealing with "the anatomy of the animal," or "the microscopic structure of the shell" which protects it. These subjects are very technical, and for our present purpose may be left almost entirely out of consideration.

Space will not permit of my entering into any great detail, and this must be my apology for the incompleteness of these preliminary remarks.

First, then, as to the origin of the term Brachiopoda, as proposed by Cuvier in 1805, which has since been very generally adopted. It is derived from the Greek

* British only.

(βραχίων, an arm; πούς, πόδος, a foot), and implies that the animal was "arm-footed." This term Professor King and others objected to on the ground that it was a misnomer, as undoubtedly it is.

Cuvier was evidently under the impression that the two labial or brachial appendages—the skeletal supports of which we sometimes find in our fossil forms—improperly designated as arms or feet, served as organs of locomotion.

We shall have occasion to refer to these appendages again later on.

Although Professor King objected to Cuvier's term, he was not the first to substitute another name; he simply followed Blainville, who, in 1824, proposed as a substitute for "Brachiopoda" the title "Palliobranchiata" (*pallium*, a mantle; *branchiæ*, gills), on account of the respiratory system being, in his opinion, combined with the mantle on which the vascular ramifications are distributed (10, p. 287).*

This, however, need not concern us greatly; for whilst we are prepared to honour Blainville in giving the most appropriate name to this group of animals, we are, nevertheless, disposed to use Cuvier's term as being the one most generally in use among students of palæontology at the present time.

The brachiopods are inhabitants of the sea; none have yet been found in estuarine, brackish, or fresh-water areas; hence we may safely infer that the rocks in which brachiopods occur are of marine origin.

As a class they have been represented by some form or other, almost uninterruptedly, throughout the whole of

* These numbers in parentheses refer to the Bibliography, and to the page of the works referred to.

the geological periods; from the oldest deposits known to contain vestiges of animal life up to the present time.

So prolific were they during the Silurian epoch that that period is often described as "The age of brachiopods."

As a class the Brachiopoda certainly appear to be dying out. Many of the forms which existed during the deposition of the Palæozoic and Mesozoic rocks are now quite extinct, such as the well known genera *Athyris*, *Atrypa*, *Chonetes*, *Lingulella*, *Orthis*, *Pentamerus*, *Productus*, *Retzia*, *Spirifer*, *Spiriferina*, *Strophomena*, and others. Some, however, had a great range in time. Such, for example, are the genera *Lingula*, *Crania* and *Discina*, all of which have persisted, with slight modifications in form, from the earliest epoch represented by fossiliferous rocks up to the present time.

Davidson, in 1884, enumerated some 74 genera, about 887 species, and 80 named varieties, which he figured in his monograph as occurring in the British rocks (10, p. 394).

This is by no means an exaggerated estimate of the British species, neither does it give us anything like an approximate idea of the whole number of species known to have existed on the globe, between three and four thousand having already been described or figured by various palæontologists in different parts of the world.

The number of brachiopods living at the present time, so far as genera and species are concerned, is very limited indeed; roughly speaking, about 22 genera and subgenera, and about 99 named species, and 29 uncertain ones (11, p. 4).

Judging by what we know of the rocks in which they are entombed, the organic remains associated with them, and the habitats of many of the recent forms, we may safely infer that the brachiopods of ancient times, like those of the present day, lived, some in very deep water, others in water of moderate depth, while others again lived in comparatively shallow water.

The recent forms are apparently gregarious, and being very prolific, they usually occur in vast numbers in their favourite haunts (10, p. 336). The same may be inferred respecting the fossil forms, which no doubt lived under very similar conditions. Unmistakeable evidences of this are to be found in the Jurassic rocks of England. In the Middle Lias Marlstone-rock of some parts of the Midland counties *Rhynchonella tetrahedra* and *Terebratula punctata* and its allies occur in such numbers as to practically constitute distinct beds. The same may be said of the Upper Trigonia-grit of the Cotteswolds which is literally crowded with *Acanthothyris (Rhyn.) spinosa*, *Ter. globata*, and other brachiopods. The Ooliticmarl of the Cotteswolds, particularly at Wall's quarry, near Brimscombe, is another instance in point; in fact at some levels it is not much unlike a conglomerate of *Rhyn. subobsoleta* and *Ter. fimbria*.

An interesting point in connection with the Brachiopoda is their great variability in size, shape, ornamentation, and thickness of shell.

In size they vary from the microscopic *Thecidea* and *Zellania*, found in the upper beds of the Inferior Oolite of Dundry, up to the giant *Productus* of the Carboniferous period, one specimen of which (*Productus giganteus*), figured by Davidson, was nearly a foot in breadth by something less in length.

Their variability in shape is quite proverbial, and every student of this group of shells will be prepared to endorse the remarks of Davidson, that "So great is the modification in shape in the same species and in the larger number of forms, that one is continually at a loss to draw even a conventional line between two closely allied so-called species" (10, p. 288).

To this we may also add, that not only is it difficult to draw a line of demarcation between two closely allied species, but it is sometimes equally difficult, from external appearances alone, to separate the individuals of two well-defined and established genera — *Magellania* (*Waldheimia* King) and *Terebratula* to wit.

In the character of their ornamentation, too, the Brachiopoda vary very considerably.

Among the fossil forms we occasionally meet with some which have retained their original colour-markings, as *Dielasma* (*Ter.*) *hastata*, and *Discina nitida* from the Carboniferous; *Ter. intermedia* from the Cornbrash; *Ter. biplicata* from the Upper Greensand; and *Zeilleria ?* (*Wald.*) *perforata* from the Lias. A specimen of the last-named form, showing colour-markings, which I found in the Lower Lias of Stout's Hill, Bitton, was figured and described by my friend, Mr. E. Wilson, F.G.S., and is now on view in our city museum. It is a very beautiful specimen, and shows how handsome some of the fossil forms must have been (21, p. 458).

Another noticeable feature in the Brachiopoda is the great difference in the thickness of the shell; some being almost semi-transparent and fragile, such as *Lingula*, etc., while others attain to very near an inch in thickness—*e.g.* the ventral valve of *Productus llangollensis*, Carboniferous.

Hitherto I have alluded to the shell of the brachiopod as if it were only a single shell; as a matter of fact it is double—the soft parts of the animal being protected by a shell composed of two distinct pieces or valves, which are practically symmetrical or equal-sided; hence they are said to be equilateral. They are not, however, equivalve; one of the valves being usually larger than the other. In this respect they differ from the Pelecypoda or true bivalves, which are usually equivalve, but inequilateral.

The valves are either articulated by means of two curved teeth developed from the margin of the ventral valve, which fit into corresponding sockets in the smaller valve, or they are inarticulated, in which case the valves are maintained in position by muscular action alone.

The inarticulated brachiopods belong to the group Lyopomata of Owen, or the Tretenterata of King; while the articulated belong to the Clisterentata of King, which is equivalent to the Arthropomata of Owen.*

The large valve is usually called the ventral valve, the small one the dorsal valve. Other names have been given, and various reasons assigned for so doing; but ventral and dorsal are the two best adapted for our purpose.

The ventral valve in many of the genera, especially in the Terebratulidæ, has a more or less pronounced beak, which is generally perforated at or near its extremity by a circular foramen, which serves for the emission of a bundle of muscular fibres called the peduncle, by which the animal forming a byssus at one end attaches itself to some submarine object.

* This division for all practical purposes will serve us. We must not, however, forget that a more modern grouping of the Brachiopoda is now adopted by many of our eminent palæontologists. It is as follows :—

I. Atremata. Examples: *Paterina*, *Obolus*, *Trimerella*, *Lingulella*, *Lingula*, etc.

II. Neotremata. Examples: *Crania*, *Discina*, *Discinisca*, etc.

III. Protremata. Examples: *Orthis*, *Strophomena*, *Leptœna*, *Chonetes*, *Productus*, *Thecidea*, etc.

IV. Telotremata. Examples: *Atrypa*, *Cyrtia*, *Spirifer*, *Spiriferina*, *Rhynchonella*, *Terebratula*, *Terebratulina*, *Magellania*, etc. (6, pp. 65–76).

The foramen is partly or entirely margined by one or two plates called the deltidium.

In other forms there exists a triangular fissure, which either remains open or is partly arched over by a pseudo-deltidium. In some other forms again, such as *Cyrtia exporrecta*, *Leptœna* (*Strophomena*) *rhomboidalis* and others, a circular foramen exists in the young individual at the extremity of the beak or in some part of the arched deltidium, and continues open for some time, but becomes closed or cicatrised in the adult (10, p. 289).

The development, shape, size, and position of the beak, foramen, and deltidial plates are all very important characters in the determination of species and varieties.

Some genera, however, such as *Lingula*, have no perforation—the peduncle simply passes up between the apices of the valves; while others, such as *Crania* and *Thecidea*, adhere to submarine objects by a portion of the surface or substance of the ventral valve. Then again there are others which were furnished with spines on the surface of the valves, which they wound round various objects for attachment, such as *Etheridgina* (*Productus*) *complectens*, and other species. Others, which are believed to have been attached in the young state, were free in the adult, such as some of the Spiriferidæ; while some seem to have never been attached at all (10, p. 289).

The peduncle is seldom met with in the fossil condition. The only instances of its occurrence of which I know are the one or two cases recorded by Davidson in his "Silurian Monograph" and its Supplement, and a specimen of *Ter. punctata, var. haresfieldensis*, which I found in the so-called Cephalopod-bed of the Inferior Oolite at Wotton-under-Edge, Gloucestershire. There may be, and most probably are, other instances on record which have not yet come to my notice.

The peduncle varies considerably in length among the recent forms. In some species it is so short that it is hardly observable outside the foramen, whilst in the Lingulæ it attains and sometimes exceeds half a foot in length. No doubt the same marked variability characterised the fossil forms.

The structure I next wish to direct attention to is the calcareous or semi-calcareous loop or supports for the cirrated brachial or labial appendages, which, as before stated, have been improperly designated arms or feet. This is by no means an easy task, and I am fully alive to the difficulties which must necessarily meet me in trying to make myself understood without illustrating my remarks with numerous diagrams and actual specimens.

The interior of the shell, with the exception of the pallium or mantle which secretes it, and the small space occupied near the beak by the digestive organs—so-called liver—and muscles, is almost entirely filled up by the labial appendages, which in reality are lateral prolongations of the mouth. These are of considerable length, closely coiled up, and fringed on one side with lateral processes or cirri.

It is almost certain that these beautiful appendages, by means of their cirri and cilia, are not only instrumental in carrying floating nutritious particles to the mouth (which is situated between the appendages at their origin), but are subservient to the functions of respiration.

The food of the Brachiopoda consists of infusoria and other minute organisms (10, p. 333).

As might be supposed, in the classification of the Brachiopoda into families and sub-families, genera and sub-genera, palæontologists attach great importance to the shape and position of the loop which acted as a support, or partial support, for the labial appendages. Without a knowledge of these loops many of our fossil forms could not have been so systematically arranged as they are at the present time. These loops—or portions of them—and a few muscular impressions on the inner surface of the valves, are in many of the extinct genera the only remains left us of the internal parts of the animal.

We possess a fairly good knowledge of the internal structure of many of the genera, but there still remains a good deal of careful and painstaking work to be done before our knowledge can in any way be said to be complete. The voluminous literature dealing with the Brachiopoda has not yet given us all the information we require, and there is still ample scope left for the student and collector.

Much might be done by those interested in this group, and having time at their disposal, in developing the loops of many of our Jurassic species.

The need of this kind of work will be understood more fully when we come to deal with King's genus *Waldheimia*.

All specimens that are found showing any internal structure—*i.e.* muscular impressions—or any portion of the loop, should be very carefully preserved.

Another item of great importance, and to which more attention should be given, is the collecting of specimens *in situ*, and thus fixing their particular horizons, as far as possible. It is all very well to collect from loose blocks of stone or refuse heaps in the quarries, but it is infinitely better to carefully collect from the beds themselves. This enables one not only to fix their particular horizons with precision, but it also gives us a better idea of the associated organisms.

It is also a matter of great importance not to reject specimens which cannot at first be readily identified. There is a general tendency among collectors to place in their cabinets only good and well-defined typical specimens, and to reject those which are intermediate in form between two closely allied species. This is a great mistake, as many of these intermediates are very often of greater importance to the brachiopodist than the typical specimens. Neither should we too hastily reject fragmentary shells before carefully examining them.

Before concluding these erratic remarks I should like to point out another direction in which original research might be profitably conducted. That is the working out of the "Evolution of the Brachiopoda"—a difficult task it must be admitted, but, nevertheless, a most interesting one. Much has been done in this direction during the past few years by Messrs. C. E. Beecher, J. M. Clarke, W. H. Dall, J. Hall, and others, of America; P. Fischer, L. Joubin, and P. D. Œhlert, of France; and other distinguished *savants* (10, p. 5).

Fully alive to the fact that I have not stated one quarter of what might be said respecting this interesting class of molluscs, I am compelled by considerations as to space to abstain from adding any more. We will therefore proceed at once to a consideration of the Jurassic Brachiopoda.

Under the term Jurassic is included the whole of the strata from the *Psiloceras* (*Am.*) *planorbis* beds of the Lias, up to and including the Purbeck beds.

I purpose following Davidson in his division of these rocks as adopted by him in his Monograph, not because it is an altogether perfect classification from a palæontological standpoint, but because we shall frequently have to refer to his work, and because it is the one most generally in use at the present time.

It is as follows :—

Lower, Middle, and Upper Lias.

Lower Oolites, including the Inferior Oolite,* Fuller's earth, Stonesfield slate, Great Oolite, Bradford clay, Forest marble, and Cornbrash.

Middle Oolites, including the Oxfordian and Corallian rocks.

Upper Oolites, including the Kimeridge clay, Portland rocks, and Purbeck beds.

The zonal distribution of the Brachiopoda is a matter of great importance, and must be studied in great detail before we can ever hope to satisfactorily understand the evolution of this group of animal life.

In a general way I purpose adopting the classification of the Brachiopoda proposed by Davidson, although here and there it will be necessary to make certain modifications in his system which recent advancement in our knowledge would seem to require.

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* Although palæontologically incorrect to do so, I have, for convenience, included the whole of the Yeovil, Midford, and Cotteswold Sands in the Inferior Oolite (I).

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LINGULA, Bruguière, 1792.

Etym.—*Lingula*, a little tongue.

In this genus the valves of the shell are held in apposition by muscular action alone, and not by means of an hinge, as in the case of *Terebratula*, *Rhynchonella*, etc.

There is no foramen for the emission of the peduncle, although there is a groove for its passage in the ventral valve. Neither is there any shelly support for the labial appendages.

Unlike the majority of the Brachiopoda, the shells of *Lingulæ* are almost entirely composed of a horny animal substance.

This genus is represented in the strata under consideration by eight species, four of which are characteristic of the Lias and four of the Oolites.

L. beanii is a typical species of the genus, and was, in 1851, the only species known in the Jurassics of this country.

Lingula first made its appearance in the Cambrian period, and has persisted, with slight variations in form, up to the present time; eight species and three doubtful ones are found in existing seas.*

Localities.†

L. beanii, Phillips, Up. Lias (?), Dundas Aqueduct, near Limpley Stoke, Somerset.

L. brodiei, Dav., Coral rag, Wheatley, Oxon.

L. davidsoni, Oppel, Lower Lias, Gloucester.

L. metensis, Terquem, Lower Lias, Stonehouse and Churchdown, Gloucestershire.

* In all instances where the number of living species is given this is stated on the authority of Davidson (11, p. 4).

† Only those localities within easy reach of Bristol, or accessible therefrom by cheap excursion trains, will be noted in this paper.

L. ovalis, Sow., Kim. clay, Weymouth.

L. sacculus, Dewalque, Middle Lias, Bathford, near Bath.

This ought to stimulate us in this district to search for some of these species, especially for *L. davidsoni*, *brodiei*, and *beanii*.

The first of these, *L. davidsoni*, named by Oppel, Davidson never saw, while *L. brodiei* was named by Davidson from an incomplete single valve found by the Rev. P. B. Brodie.

DISCINA, Lamarck, 1819.

Etym.—*Discus*, a disk.

Like the Lingulæ, the shell in this genus is of a horny animal substance, inarticulated, and destitute of shelly supports or loop for the labial appendages. It is more or less orbicular in shape, and the upper or dorsal valve being somewhat conical gives a patelloid or limpet-like appearance to the shell.

The lower or ventral valve is depressed, flat, or slightly convex, and is affixed to submarine objects by a tendinous peduncle issuing through a small slit or fissure (foramen), varying in length and size, extending from its centre to near the margin (7, p. 9).

The peduncle is so short that the shell appears to be attached by the ventral valve or some portion of its substance, as in *Crania*.

This is the most persistent of all our British fossil Brachiopoda; if we include in this genus those shells now called *Disciniscа*, it has been found in all the geological formations, from the Silurian up to existing seas, where it is represented by some seven or eight species.

From what we know of the recent Discinæ and Lingulæ it is generally supposed that the rocks in which the fossil forms are found were deposited in seas of very moderate depths, there being no reason to believe that the same kind of animals in past times lived under very dissimilar conditions to those now existing.

D. babeana, d'Orb.=*D. townshendi*, Forbes, it may be mentioned, is the sole representative of the Brachiopoda in the Rhætics of this country.

Of the twelve species from the Jurassics, eight are found in the Oolites.

LOCALITIES.

D. dundriensis (type), Moore, Inferior Oolite, Dundry.

D. davidsoni (type), Moore, Lower Lias, Bedminster Down.

D. etheridgei, Dav., Inferior Oolite, Nailsworth, Gloucestershire.

D. holdeni, Tate, Middle Lias, Cheltenham, Gloucestershire.

D. davidsoni, *orbicularis*, *reflexa*, and *D.* (?) *moorei*, have been obtained from the Lias of the Ilminster district.

The type specimens of *D. davidsoni* and *D. dundriensis*, both collected and named by the late Chas. Moore, may be seen in the Bath Museum (23).

In my collection are two specimens of *Discina*, sp. nov., which I collected some three or four years ago from the Bradford clay of Bradford-on-Avon, Wilts, the first, I believe, recorded in this country from that horizon.

CRANIA, Retzius, 1781.

Etym.—*κρανίον*, a skull.

Shell inarticulated; no foramen, peduncle, or calcareous supports; fixed to marine bottoms by a portion of the surface or substance of the lower or ventral valve.

The species of this genus vary very greatly in shape and ornamentation — some are almost circular, others subquadrate, transverse, or elongated. In general appearance the shell is patelliform.

Its range in time is from the Silurian up to existing seas, where four or five species are found.

Four species are recorded from the Lias, and three from the Oolites.

LOCALITIES.

C. antiquior, Jelly, Gt. Oolite, Hampton Cliff, near Bath.

C. canalis and *sandersii*, Moore, Inferior Oolite, Dundry.

The types of *C. canalis* and *sandersii* were, I believe, both found in the Inferior Oolite of Dundry by Mr. Moore, and named by him; but both are missing from his collection in the Bath Museum.

CADOMELLA, Munier-Chalmas, 1887.

Etym.—*Cadomum*, Caen, name of a town.

Syn.—*Leptæna* (?), Davidson, 1884.

Œhlert describes the shell of *Cadomella* as "nearly flat or slightly concavo-convex, with a transverse form; cardinal line long and straight; umbo of ventral valve scarcely more prominent than that of the dorsal valve; area linear, with pseudo-deltidium and 'talon' of the process prominent" (16, p. 1285). This is followed by an excellent diagnosis of the internal structure; *i.e.* cardinal teeth, muscles, median septum, etc.

The type of the genus is the *Leptæna* (?) *moorei* of Davidson, which was found so plentifully by Moore, with *C.* (?) *davidsoni*, E. Desl., in the Leptæna (?) beds of the Upper Lias of Ilminster.

Cadomella is apparently confined to the Lias, and in this country is represented by the two species above named.

As in *Zellania*, *Spiriferina*, and *Köninckella*, the animal is unknown. A described dorsal valve of *C.* (?) *davidsoni* is in the Bath Museum.

KÖNINCKELLA, Munier-Chalmas, 1880.

Etym.—Dedicated to L. G. F. de Köninck, naturalist.

Munier-Chalmas' diagnosis of *Köninckella* is very brief indeed, as recorded by Davidson (10, p. 278).

Œhlert gives a much more exhaustive account, and describes the shell as "Concavo-convex, smooth, with the valves very close together, cardinal line narrow, and the general form of which recalls a *Leptæna*; cardinal process subrectangular and prominent." Then follows a description of the spiral appendages which were furnished with thread-like spines (16, p. 1292).

The type species is the *K. liasiana*, Bouchard sp., which is found, with *K. bouchardi*, E. Desl., in the Middle Lias of Ilminster. Only one other species is found in this country, viz., *K. rostrata*, E. Desl., Middle Lias of Whatley, near Frome, and Mungar, near Radstock.

SPIRIFERINA, d'Orbigny, 1847.

Etym.—Diminutive of *Spirifera.*

Formerly all the Spiriferinæ were placed in Sowerby's genus *Spirifera*, but the presence of a median septum, and an important difference in the shell structure of the Spiriferinæ, warranted their separation from the Spiriferæ, to which in external shape and ornamentation they are closely allied. The shell structure in *Spiriferina* is punctated; in *Spirifera* it is not.

The space intervening between the dental plates in the interior of the ventral valve, in *Spiriferina*, was occupied by the cardinal muscles, which were divided by an elevated mesial septum, wide and thick at its base, but gradually tapering into the shape of an acute blade, to the sides of which the adductor muscle was, no doubt, fixed (8, p. 82). This septum is absent in *Spirifera*.

Spiriferina may be distinguished externally from any other Jurassic brachiopod by the following features:—"Well-pronounced, imperforate beak; beak-area well defined, which is in most of the shells largely developed and interrupted by a pseudo-deltidium, notched in the vicinity of the cardinal edge; also by the well-defined and strongly marked hinge-line and area."

Spiriferina first appeared in the Devonian period, reached its maximum development during the Liassic epoch, and appears to have died out in the Oolitic epoch. Fourteen species are found in the Jurassic rocks, including *S.* (?) *moorei*, Dav., and *S. signiensis*, Buv. (?) from the Lias; also *S.* (?) *minima* and *oolitica*, Moore, from the Inferior Oolite of Dundry, which are provisionally refered to this genus. Most of the other species are from the Middle Lias.

S. walcotti, Sow., is assuredly one of the most handsome of the Spiriferinæ—or indeed of the Brachiopoda: from no other part of the country can such fine and well preserved specimens be obtained as from the Lower Lias of the Radstock district. Two described specimens from this district is located in the Bath Museum; also types of—

S. (?) *minima*, Moore, from the Inferior Oolite of Dundry.
S. (?) *oolitica*, ,, ,, ,, ,, ,,
S. münsterii, Dav., from the Middle Lias of Ilminster.

RHYNCHONELLA, Fischer de Waldheim, 1809.

Etym.—ῥύγχος, a beak.

This interesting but extremely difficult group of shells is so well known that it is quite unnecessary to describe in any detail the external shape of the shell, or its ornamentation.

The apophysary system in the dorsal valve is composed of two short, flattened, and grooved lamellæ, separate, and moderately curved upwards, attached to the inner side of the beak of the smaller valve, and to which are affixed the free spiral fleshy labial appendages; a small central longitudinal septum, more or less elevated, extends along the bottom of the smaller valve from under the beak to about half or two-thirds the length of the shell, separating the muscular impressions visible on either side (7, p. 65).

The genus has a wide geological range, being represented in all the formations, from the Silurian up to the Tertiaries. It is represented in existing seas by its congener *Hemithyris*, of which five species are known.

Rhynchonella attained its maximum development in the Jurassic epoch, where it is represented by sixty species and ten varieties.* In this number are included *R. hampenensis*, S.S.B. (2), from the Inferior Oolite of the Cotteswolds, which has been named since 1884; also *R.* (?) *coronata* and *lopensis*, Moore, which are doubtfully placed in this genus: but not the spinose Rhynchonellæ (*Acanthothyris*).

Of this number no less than twenty-five species and one variety † are found in the Inferior Oolite, while only nine

* *Vide* Appendix.

† Certain of the varieties of this and other genera are considered by some palæontologists to be distinct species; there are others however who would considerably reduce the number of species and make them varieties only. This difference of opinion, unfortunately, is likely to exist for some time to come. I have therefore recorded as varieties those which Davidson considered to be such, although personally I feel confident that many of them are specifically distinct. For instance, Davidson considered *R. subangulina* to be a variety of *R. angulina*, which in my opinion is a mistake. *R. subangulina* occurs much earlier in geological time, viz. in the *Murchisonæ* zone, whilst *R. angulina* occurs in the *Parkinsoni* zone. On this supposition, the variety would have come into existence before the typical form from which it was derived.

species and six varieties are recorded for the other divisions of the Lower and Middle Oolites. *R. subvariabilis* and *inconstans* from the Kim. clay, and *R. portlandica* from the Portland rocks are the only three species found in the Upper Oolites.

The Rhynchonellæ are undoubtedly the most difficult and troublesome group of brachiopods which the student has to contend with, that is so far as the species are concerned. In the same species we often find specimens very convex and gibbous, while others are comparatively depressed or flat; the number of plaits or ribs in the valves of the same species may vary considerably, these not infrequently form a more or less well pronounced or elevated mesial fold, which in the same species may consist of only one plait, or of two, or three, as in *R. cynocephala.*

The shape and position of the beak and the deltidial plates also vary.

Another great difficulty we sometimes experience is the great difference of shape assumed during the different stages of growth. The shell in the young state may be depressed, with beak straight and deltidial plates clearly shown, but in the adult the shell may be very convex, the beak quite incurved and the deltidium quite obscured, as is sometimes the case in *R. varians*, var. *smithii*, *concinna*, etc.

Then again in the young we may have the plaits well shown, extending right down from the umbo to the front margin of the shell, while in the adult these may become evanescent towards the umbo, as in some forms of *R. lineata*, var. *radstockensis*; or the simple plaits of the young form may unite in pairs in the older stage so as to become bifurcated, as in *R. rimosa*, *furcillata*, etc.

It is therefore necessary to take all these general characters into consideration when arranging the species of

Rhynchonella, and even then the task is not infrequently very difficult.

The geographical distribution of the Rhynchonellæ is very interesting. Species found in one district may be altogether absent in another. Even in the same bed of rock a certain species may be found in one point in great numbers, while at a distance of a few yards away it may be quite rare or altogether absent. Many species were very prolific during the Jurassic epoch, others such as *R. wrightii*, *egretta*, *fallax*, *dorsetensis*, *dundriensis*, and a few more are extremely rare.

The type of *R. dundriensis*, from the Inferior Oolite of Dundry, is located in our museum (23), while the types of the following Rhynchonellæ are carefully preserved in the Bath Museum :—

R. bouchardii, Dav., from the Upper Lias of Ilminster.
R. (?) *coronata*, Moore, ,, ,, ,, ,,
R. moorei, Dav., ,, ,, ,, ,,
R. pygmea, Morris, ,, ,, ,, ,,
R. sub-concinna, Dav., ,, Middle ,, ,,

R. (?) *lopensis*, Moore, Inferior Oolite, Lopen, near Ilminster. Also described specimens of

R. furcillata, Theodori, Middle Lias of Ilminster.
R. serrata, Sow., ,, ,, Moolham.
R. tetrahedra, Sow., ,, ,, Ilminster.

ACANTHOTHYRIS, d'Orbigny, 1850.

Etym.—*ἄκανθα*, a spine; *θυρίς*, a small opening.
Syn.—*Rhynchonella*, Davidson, 1884.

A. (*Rhyn.*) *spinosa*, Linn. A shell of the upper beds of the Inferior Oolite is the type of this genus.

The external surface of the valves of *Acanthothyris* is more or less covered with spines, some of which, as in *A. spinosa*, attain a great length.

Prior to the publication in 1889 of Messrs. Buckman and Walker's Memoir on *Acanthothyris*, only three species and one variety had been recorded, *viz. A. spinosa*, *crossi*, and *panacanthina*—mistaken by Davidson and other English palæontologists for *A. senticosa*, Schl. sp.—all from the Inferior Oolite, and *A. spinosa*, var. *bradfordensis*, from the Bradford clay of Bradford-on-Avon, etc.

To this number they added:—

A. spinosa, var. *obornensis*, B. and W., Inferior Oolite.

A. „ „ *powerstockensis*, B. and W., Fuller's Earth.

A. paucispina, B. and W., Inferior Oolite.

A. „ var. *cortonensis*, B. and W., Inferior Oolite.

A. tenuispina, Waagen, Inferior Oolite.

A. senticosa, Schl., var. *fileyensis*, B. and W., Lower Calcareous Grit and Passage beds (3).*

A. spinosa is the most prolific of the species. Wherever the Upper Trigonia-grit is exposed in the Cotteswold range of hills it is exceedingly abundant, but as we travel in a south-westerly direction through the counties of Somerset and Dorset it becomes, in comparison, rare. On the other hand, *A. panacanthina*, which is often found in Dorset and Somerset, is exceptionally rare, if not altogether absent, in the Cotteswolds.

It may be mentioned that Davidson strongly deprecated the generic separation of the spinose from the non-spinose Rhynchonellæ.

In the geological series *Acanthothyris* is apparently confined to the Oolitic rocks. A living specimen has, however, been found in Japanese waters, *A. döderleini*, Dav. This is preserved in the Strassburg Museum.

* *Vide* Appendix.

TEREBRATULINA, d'Orbigny, 1847.

Etym.—Diminutive of *Terebratula*.

The Terebratulinæ may be distinguished from the Terebratulæ, to which they appear closely allied, by several well-marked features.

The shell may be described as generally longer than wide, and more or less oval in shape; the beak is obliquely truncated by a foramen, which generally extends to the umbo; deltidium small, and at times indistinct, or entirely absent; sometimes the dorsal valve exhibits two variously developed auricles or ear-shaped expansions. External surface of the valves striated or costellated. Articulated like *Terebratula*. Loop short, and rendered annular by the union of the oral processes in the form of a band. Labial appendages, which project considerably into the interior of the shell, supported by the crura (8, p. 63) (20). Shell structure punctated.

Davidson recorded the following species as occurring in the Jurassic rocks of this country :—

T. radiata, Moore, Great Oolite, Hampton Cliff, near Bath.

T. „ var. *dundriensis*, Dav., type from the Inferior Oolite of Dundry.

T. (?) *deslongchampsii*, Dav., Middle Lias, Whatley, near Frome.

T. (?) *granulosa*, Dav., Upper Lias, Ilminster.

T. substriata, var. *suffieldensis*, has since been named by Mr. Walker. It came from the Lower Coral rag of Suffield, near Scarborough (20).

Excluding *T.* (?) *deslongchampsii* and *granulosa*, which are doubtfully placed in *Terebratulina*, the genus may be said to have first made its appearance in the Oolitic seas. It has persisted through the Cretaceous and Tertiary rocks, and is represented at the present time by eight species and six uncertain species.

Whether or not the promotion made by Fischer and Œhlert of the recent *T. wyvillei*, Dav. sp. as the type of their new family Dyscoliidæ, will carry with it other recent Terebratulinæ, or otherwise interfere with the present arrangement of our Jurassic species I am not prepared to say (6).

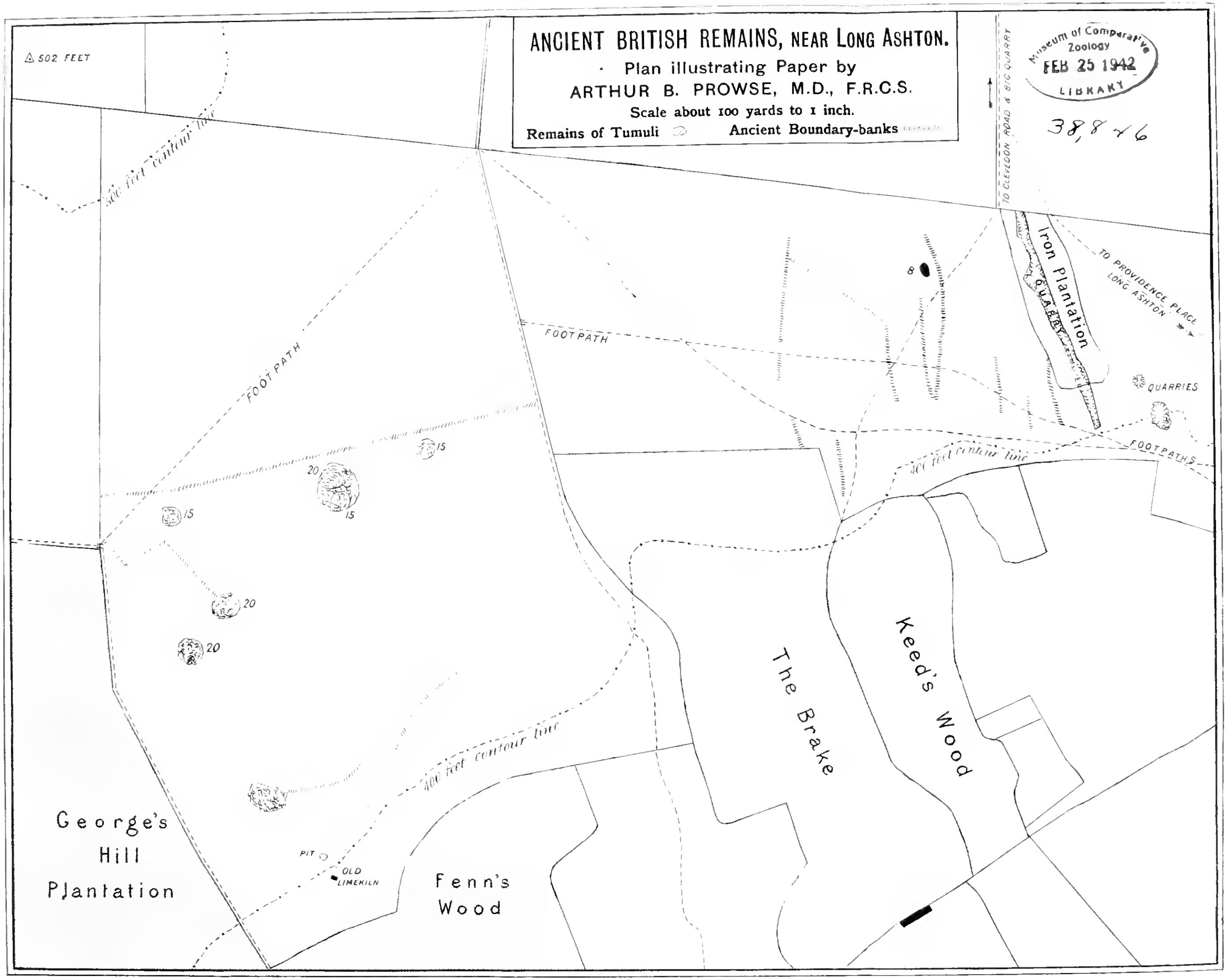
DISCULINA, Eug. Deslongchamps, 1884.

Etym.—Diminutive of *disculus*, a little disk.

Deslongchamps' description of *Disculina* is as follows:—"Shell quite discoidal; ventral valve regularly convex; dorsal valve absolutely flat, nearly in the form of an operculum. Surface ornamented with fine striæ, regularly and very equally disposed in a radial series. Large valve furnished with a well pronounced area, in the centre of which is perforated a broad, rounded foramen, completed below by two little lateral deltidial plates, which do not unite together on the median line. Interior presenting an identical appearance in the form of the plateau and of the cardinal region to that of *Terebratulina*. Brachial apparatus unknown." (12, p. 241).

Disculina is represented in this country by one species only (the type), the very rare and handsome *D. hemisphærica*, Sow. sp., which may be occasionally met with in the Great Oolite of Hampton Cliff, Kingsdown, and Farley, near Bath.

Davidson included this species first in *Terebratella*, and afterwards in *Terebratula*.



ANCIENT BRITISH REMAINS, NEAR LONG ASHTON.

Plan illustrating Paper by ARTHUR B. PROWSE, M.D., F.R.C.S.

Scale about 100 yards to 1 inch.

Remains of Tumuli   Ancient Boundary-banks

Some Ancient British Remains near Long Ashton, Somerset.

(*With Map.*)

By ARTHUR B. PROWSE, M.D. Lond., F.R.C.S. Eng.

Read Oct. 4th, 1894.

IN Vol. VII. (New Series), 1892–94, pages 93 to 104, is printed a paper I read in April, 1893, upon some records of prehistoric times which may still be seen on our own delightful Downs. The following notes refer to a very similar group which exists on the open breezy hill, some distance west and north-west of Long Ashton, about 3½ miles in a bee-line from this building. The elevation is about 200 ft. higher than our Downs, varying between 400 and 500 ft.; and the ground on which the remains exist slopes mainly towards the S.E., a favourite aspect for the settlements of prehistoric man in this fair island home of ours. On pages 94 to 101 of the above-mentioned volume is a classified list, and brief summary, of the various stone remains which may reasonably be attributed to our ancestors in pre-Roman times, and of their leading features. To this I will refer you for information, and not occupy time by a mere recapitulation.

The easiest way to reach these Ashton antiquities is to cross the Suspension Bridge, and pass along the road skirting Nightingale Valley; and then through Beggar Bush Lane to its ending. Turn now to the left, along the road bounding the west end of Ashton Park, as far as where there are some large wooden gates in the boundary wall. On the other side of the road is a gate. Enter the field through this and go south, along the east side of the limestone quarry and kilns, to a gateway leading into the high road from Clevedon, which passes towards Bristol through Clarken Combe. Directly opposite is another gate, from which a footpath runs by the side of a hedge to a stile, close to the N.W. corner of a small copse (called "Iron Plantation" on the map), which surrounds an old, and unused, quarry of a peculiarly narrow, elongated shape. To the west of this wood we come upon the first portion of the group of ancient remains. The ground, in the summer and autumn, is covered with long coarse grass and tall bracken, so that it is not by any means easy to trace the course of some of the *Banks* of earth and stone which exist here. Some of them are, however, well-marked and prominent objects; but even these, when they approach the modern stone fences and hedges which enclose the ground, become less in size, and ultimately disappear. The fence-builders have evidently utilized the loose, moderate-sized stones of which they were mainly composed. Seven distinct *Banks*, which run almost due north and south, can be traced for distances varying from 20 or 25, up to 120 or 130, yards. Another which runs for 90 yards, from N.W. to S.E., joins two of the former Banks obliquely.

Eight yards west of the central one of the seven nearly parallel Banks, and 25 yards from its northern end, is an oval mound, about 9 by 7 yards in size. This, I am inclined to think, represents the ruins of one of the circular, or nearly circular, Hut-dwellings of the primitive folk. If leave were obtained from the owner of the ground, it would be well worth while to dig into its centre, and to carefully examine the earth thrown out.

This plan has been very successfully carried out upon Dartmoor, within the last year or eighteen months, by some members of the "Dartmoor Exploration Committee," to which I belong. Specimens of flint weapons were found in the floor of several of the Hut-circles, and one or two "querns," or stones for grinding corn; together with "cooking-stones." No metal whatever, bronze or iron, was discovered; and this of course indicates a very high antiquity.

In the case of these Dartmoor circles, many people, fond of theorizing, had asserted that they were merely the ruins of *mediæval* tin-miners' huts. They cannot now maintain their scepticism as to the great antiquity of, at any rate, a large number of these "Hut-circles."

With the exception of the one mentioned, I have not found near Long Ashton anything like the remains of such huts. A more likely position would have been rather further down the hill-slope, in a less exposed place; but here the ground is partly meadow-land, and partly planted with trees, so that any ancient remains which may have existed must almost certainly have been completely destroyed by agricultural operations.

If we now leave this part of the hill, and pass through a gate, about 200 yards west of the most westerly Bank, we shall enter another large enclosure of untilled ground 300 to 400 yards wide, and 600 to 700 yards long. Right across this, nearly east and west, is a small Bank or Trackline of stones and earth. South of this, at different distances, are the wasted remains of six, or perhaps seven, large *Cairns*, or stone tumuli. Their component stones have almost all been carried off, for building the neighbouring stone fences, or for burning into lime.

There still remains the ruin of a small, old-fashioned kind of limekiln, about 50 yards from the south side of the field. Near this the Ordnance surveyors have inserted the word "Quarries"; but the only visible sources of stone for burning into lime, with the exception of a very small circular pit, a few yards from the kiln, are the Cairns further up the hillside. The Cairns are all from 15 to 20 yards in diameter; but two of them which lie close together in the central part of the field are surrounded by a stony area 40 yards across; and it is just possible that this area represents the extent of one huge Cairn, and the two aggregations of stones, which I have considered the remains of two, distinct, smaller Cairns, may be merely portions of this supposed larger one.

About the centre of the western boundary-wall of this large field-enclosure is a gate near the corner of a plantation. A few yards north of this gate a slight bank commences, and runs in a S.E. direction for 32 yards. It now bends sharply E.N.E. for 36 yards, and then suddenly resumes its S.E. course for 60 yards further, where it ends in one of the Cairns.

This completes the description, so far as observation warrants me in speaking positively. There are in various places other small ridges, especially amongst the group of boundary-banks first mentioned; but they may be merely *natural*, and not artificial, irregularities of the surface. On the other hand, if the long grass and bracken were completely removed, other features due to human handiwork would very probably be found, and easily traced. Thus, we find that the best time for mapping out the old stone remains on Dartmoor is in March or April, after the dead and dry vegetation of the previous year has been removed by what is called "swaling" (*i.e.* setting fire to it), and before the new grass, etc., has commenced to grow. Such a practice improves the pasture for sheep and cattle; but it could not safely be resorted to, except in wide tracts of land, where there are no trees, hedges, or buildings, but merely *stone*-fences.

The scale of the map illustrating this paper is about 100 yards to 1 inch.

Bookworms found in America.

By A. C. FRYER, M.A., Ph.D.

THE bane of the bibliophile is the bookworm. It is detested because of the havoc it works; it is, at the same time, longed for by possessors of valuable books.

The larva of *Œcophora pseudospictella*, a small brown moth, is sometimes called the bookworm; but the larva of *Anobium*, a small coleopterous insect, seems to have a still better claim to the name. The first resembles the *Anobium*, save that it has six legs, while the latter has none.

Since many chemical substances have been introduced into the manufacture of paper, the bookworm has become scarce; however, in Southern Europe the book-eating *Anobium* is still to be met with. It is very like the grub found in hazel nuts. Its body is soft, with a horny brown head and strong jaws. The *Anobium* attacks the books generally from the boards inwards, but M. Peignot asserts that he found twenty-seven volumes standing in a row, pierced from end to end by a single worm-tunnel.

So far as has been ascertained, only two of these secret enemies of books have been found in America. There may have been others, but no records of their existence have been kept.

These two worms were found by Mr. W. E. Benjamin, of New York, in a leather-bound copy of "Seneca," published in

London in 1675, and owned by John Carey in 1782. In the lower right-hand corner of page 46 a small worm lay buried in a hole it had eaten in the pages. The worm was motionless, and close to its tail was a conical cocoon. One worm began at the end of "Seneca" to eat forward, while the other began at the front and worked towards the end. These worms appear to be the first of their kind found in America.

The account from New York states that the worm eating in the front of the book was about three-eighths of an inch long and one-eighth of an inch in diameter. Its head ended bluntly, while its tail tapered to a sharp point. It was the colour of water mixed with oatmeal. Being disturbed by one of the many who saw it, the cocoon was torn from the paper. The worm raised itself suddenly, but almost instantly resumed its former position, deep in the pages. The American report also states that when the cocoon was examined under a microscope it appeared to have six legs, or cases, and a white median line, barely perceptible, on its inner side. At the end from which the worm had emerged were two fine horns, thinner than silk thread. There were five rings around the tail. The structure of the shell was so thin that one could easily see through it. On the third day one of the worms died. The other gave up the task of consuming the "Seneca" two days later.

This appears to be the first case of bookworms found in America; but, although the American libraries are free from the ravages of the bookworm, yet they are infested and damaged by a small cockroach—the Croton Bug, or *Blatta Germanica*.

Facts and Fancies from the Note-book of a City Naturalist.

By J. A. NORTON, M.D.

IN the autumn of '54, in North Street, Bristol, an old jackdaw's nest was found upon lighting a fire, the sticks and an old broken egg coming down the chimney.

While waiting for you to join me in a stroll from Bristol Bridge I make my next extract. During our stroll we shall make notes of birds and other animals that have been observed, but which are not given in sequence of time.

In the dim grey of a frosty Sunday morning in November, I heard a whizz past my ear. Thinking that some one had thrown a cocoa-nut husk at me, I turned, but saw no one. The idea was caused by my seeing a brown body roll down the buttress on the west side of the bridge; on looking again, two or three feathers were seen floating in the air, and a brown bird in the water, also two birds in full flight up High Street. I thought at first that it was a sparrow-hawk in the water and pigeons escaping, but a further look and subsequent capture showed the bird to be a partridge (it was caught after swimming under the Bridge), and a man coming up the street told me he had flushed three birds from a doorway in Victoria Street.

From the Bridge we can see swallows in plenty, and house-martins, also sand-martins that build in the retaining bank at the back of Bridge Street; here also bats may be watched in their beautiful flight, so different in character from that of birds.

Proceeding down Victoria Street, we notice jackdaws, pigeons, starlings, and house-sparrows nesting in the towers of St. Thomas' and the Temple Church, and also rooks on their way to Queen Square, and at the Grosvenor Hotel we stop to listen to the cheery note of the cuckoo. Arrived at Bath Bridge I ask you to notice, on the bank to our right, a small flock, seven or eight redwing and fieldfares, scratching over the dust-heaps thrown within ten yards of the Bridge on to the snow tipped over the rails. This note was made at 11 o'clock in the morning upon a great market day in '89 (I believe my date is correct).

In the artificial bed of the river may be seen a salmon occasionally, more often suffocated by mud than alive; and opposite the lock gates to our left might be seen a porpoise,—one was seen by a man who well remembers it, but it was before I took notes.

On the right-hand side of the road, by the Three Lamps, there is a colony of sand-martins, and at the cemetery gates their cousins the house-martins and swallows are in evidence.

If you will take a peep "over the garden wall" at Arno's Vale, down upon the ground you will see busily occupied among the beech leaves three nuthatches, and we watch one of them fly up with its booty; we also notice the golden-crested wren busy in the cedar where it nested a few years ago. In the corner of the market garden, on the left of Sandy Lane, we see a number of young birds, some still being fed by their parents, and distinguish among many others the yellow and pied wagtails, yellow-hammer, white-throat, redstart, fly-catcher, butcher-bird, and meadow-pipit.

Walking up the lane, we are accompanied by a merry troop of long-tailed tits, scouring the thick quickset hedge, and at the top of the lane we just miss the Stanton Drew Harriers in full cry after a hare which made good her escape.

Close by is the home of the moorhen, kingfisher, stock-dove, turtle-dove, wood-pigeon, blackcap, nightingale, and other warblers, as well as of the bullfinch, brown linnet, and other finches, and the green and great spotted woodpeckers. In the field on the right of the lane is a large flock of lapwings, and we notice a flock of sheep with young lambs, so different in appearance from their parents and the older lambs in the adjoining field.

Why has not mutilation for centuries effected the curtailment of the tail? Operation during two or three generations was to produce marvellous results in some of the monkeys, according to some recent American scientific investigators.

Coming down Kensington Hill, we notice another colony of sand-martins nesting under different circumstances between the stones of a roughly built wall; and at the turn of the road, on December 24th, '94, at 4 p.m., we see a bat noiselessly flitting by. Overhead a heron, with slow flapping, short broad wings, speeds homewards to Brockley.

Arrived at the cemetery gates, we pass through the home of many birds: green woodpecker nesting here five years since, willow-wren, and chiffchaff, fly-catcher, redstart, finches of various sorts, butcher-bird, wagtails, meadow-pipit, lark, cuckoo, great, blue and cole-tits.

Passing out at the top gates and down past the old Bush Hotel into St. John's Lane, we start a hare in the allotment grounds, and walking through the lane we flush snipe and sandpiper. Here I used to see our spring visitors as early as anywhere, and repeatedly I have seen young cuckoos in a hedge, where now is a long row of inhabited houses.

Magpies and crows' nests are to be seen from this lane, and in the alders by the Malago Street we have noticed a flock of siskins busily feeding.

Proceeding next into Bedminster over Merrywood down towards Ashtongate, I would call your attention to a flock of starlings, about whose evolutions (in the air) there have been sundry letters in the papers; thirty or forty birds are dashing about in all directions, wheeling suddenly, darting upwards, perpendicularly, and as suddenly shooting downwards, crossing and recrossing as they slowly maintain an onward course. Noticing where this procession crossed the main road, we notice bruised and broken ants in large numbers, and as the birds get clear of a belt of trees, so that there is a clear sky behind them, we can see that there is a dense column of ants, still being fed upon as it flies onwards without guidance, directed only by the light breeze, and without any chance or the power of effort at escape.

Where is the "intelligence" of the ant?

They can avoid a train, when the rails have worked loose, by going under instead of over the rails! Marvellous intelligence!

Continuing our walk, we cross the Park to the Avon and see a large variety of gulls and terns, and also the ringed plover; and opposite the Powder House one September morning, when a passenger on a steamer for Ilfracombe, I saw a cormorant rise from the water.

Returning again up Coronation Road, we look at the Board Schools recently finished at Southville; while in process of building I saw a small flight of brown birds coming towards me, it pitched on some rough broken ground, and I noticed two of the birds had a different gait, and were slightly larger than the others. On moving, there was a difference in their flight, and when they turned from me I recognised their conspicuous markings—the bright white flash which is enough to attract attention at any distance, for the wheat-ear is one of our most noticeable wild birds. This flash light must be looked upon as an absolute failure in protective colouring, and cannot subserve the same purpose that has been suggested as an excuse for the white underside of the rabbit's tail.

Having taken this stroll, may I ask you to observe a few points? The sand-martins nesting out of their usual site, a sand-bank, in holes in walls—their food supply remains,—many other birds are extinct, their nesting places and food supplies being immediately connected.

Why does the sand-martin drill holes in banks for the fulfilment of its maternal instinct? Its bill is weak, its feet diminutive, its body weight almost nil, and its tail cannot be used as a fulcrum from which to give powerful blows with a weak tool.

Why does the house-martin use its delicate beak as a hod and trowel? The bill is not what we should design for the purpose.

Why does the swallow make an open nest? Not to accommodate its tail, as has been suggested. These birds with similar habits, and we might add the case of the swift, nest differently and all apparently under inappropriate conditions.

Watch the young birds; we talk of their learning to fly—the bird is pushed out, or falls, or boldly hops on to the edge of its nest, in hedgerow or ditch, and scrambles or hops or flutters on to a twig, it gets up higher and falls, then it starts again, and gradually increasing in strength and feeling its way it flutters and flies, but the martin dives off at once; the finch or warbler can, before leaving the roofless paternal mansion, stretch its short wings, but the long-winged martin or swallow has not room in its mud hovel to exercise its powers, and before it has learnt to swim it takes its first plunge, it dives into space, and the most perfect flying machine is at once, and for life, an accomplished fact!!

We made the acquaintance of the nuthatch, and we are told by Science that the nuthatch is more nearly related to the swallow than to the woodpecker. Beak and feet are of little value in classification; internal characteristics alone are reliable. Is the mud around the nuthatch's home a reminiscence of by-gone memories—a connecting link with the ancestral swallow?

We are told that to find "the common ancestors of the wood-peckers and the swifts the geological record (the genealogical tree) need not be searched so far back as would be necessary to discover the common ancestors of the swifts and swallows." Who dares talk of common ancestors of swifts, swallows, and woodpeckers? The only one who dares to, is he who assumes powers for the created being, which he denies to the Creator.

Why do not some of the common offspring of these "common ancestors" appear in our museums? A "Jew's eye" would lose its character for value; some of these missing links would be worth to the theorist more than all eyes that ever saw light!

Many birds make nests that do not appear to be happy homes. As soon as the eggs are hatched, the home is broken up. Why do some birds lay eggs which produce young that are able to fly, run, or swim in a few hours, and that are able to feed themselves, and that merely need the parental warmth and education? Others, as the martins and woodpeckers, have to toil to make a home where "she may lay her young." To how many is the home, the nest, a source of danger during the building, whilst the eggs are being deposited, while they are being incubated, and when the young are being reared? Scores of questions may be asked, of which I have merely suggested one or two that ought to be answered by the Scientist, if he expects the Observer of Nature to believe him in his assertions as to protective colouration, natural selection, and such other phrases, which merely mean that he does not believe in the Creative Power of an Almighty who rules the universe and has made laws to prevent the multiplication of species.

Additions and Corrections to Local List of Lepidoptera.

By GEORGE HARDING, F.E.S.

IT is now some years since Mr. Hudd's valuable list of the Lepidoptera of the Bristol district was published in the Proceedings of the Naturalist Society; and as, since then, several species altogether new to the district have been found, some that were considered doubtful have been established, and a number of others that were only known to occur in one county — Gloucestershire or Somersetshire — have now been found in both counties, I thought it might be of interest if I endeavoured to make the necessary additions and corrections, so as to bring the list as nearly as possible up to date.

I shall also note the further occurrence of any species of which there then had been only one or two records. I would at the same time state that I am very largely indebted to Mr. J. Mason, of Clevedon, who has not only been very successful in taking a considerable number of species in Somersetshire, of which we previously had records only from Gloucestershire, but also has added several that are altogether new to the list.

DIURNI.

Colias Edusa, var. Helice.—Durdham Down, by Mr. Geo. Thompson, in 1894. No previous record from Gloucestershire.

Colias Hyale.—Clevedon, 1885, J. Mason.

Vanessa Calbum.—Clevedon, J. M. No previous record from Somerset.

Lycæua Ægon.—Clevedon, J. M.

NOCTURNI.

Chærocampa Celerio.—Two specimens of this rare and beautiful species, taken by Mr. Mason and another, seen over flowers at Clevedon Court Gardens.

Sesia Bembiciformis.—Clevedon, J. M. No previous record from Somerset.

Zygæna Lonicerae.—Clevedon, J. M.; Dursley, by myself, 1893. This insect is not easy to distinguish from Z. Trifolii, and specimens of the two species are often found mixed in cabinets. It will, I think, be found that Loniceræ always occur on dry hills; while Trifolii seems essentially a marsh-loving species—so much so that in the bog and marsh land of South Wales Trifolii is much commoner than the six-spot burnett Z. Filipendula.

Setina Irrorella.—This species is inclosed in brackets in Mr. Hudd's list; but there is no doubt that it occurs in several places in the district. Mr. Phillips took a number of specimens at Dursley some years ago. I took it there in June, 1895, and now I have to record its capture at Brockley on the Somerset side.

Nudaria Senex.—Walton Moor, by Mr. Mason. A species altogether new to the district.

Trichiura Cratægi.—Clevedon, J. M.

Lasiocampa Quercifolia.—Clevedon, J. M., 1888. First record from Somerset.

GEOMETRÆ.

Ennomos Fuscantaria.—Clevedon, J. M. The only previous record in Somerset being from Bath.

Nyssia Hispidaria.—Several specimens bred in 1890 from larva, taken by myself at Brockley, the previous nearest record to Bristol being Taunton. The species is practically new to the district.

Eupestera Heparata.—Clevedon, J. M.

Acidalia Ornata.—Clevedon, J. M.

Corycia Temerata.—Clevedon, J. M.; Leigh and Brockley, by myself. No previous record from Somerset.

Eupithecia Albipunctata.—Clevedon, J. M.

Eupithecia Subcilliata.—Clevedon, J. M. Both Mr. Hudd and myself thought perhaps Mr. Crotch had made a mistake in including this species among those taken at Weston-super-Mare; but Mr. Mason's captures sets the matter at rest, and serves to show that Mr. Crotch's observations were not at fault.

Lobophora Sexalisata.—Walton Moor, J. M. Quite new to the district, and a most interesting capture.

Scotosa Undulata.—Walton Moor, J. M. The only record in Somerset.

PSEUDO-BOMBYCES.

Stauropus Fagi.—Brockley Combe, Mr. Jefferies, 1886.
Notodonta Chaonia.—Brockley, Mr. Sergeant, 1887.

NOCTUÆ.

Acronycta Aceris.—Clevedon, J. M.
Acronycta Alni.—Clevedon, J. M.
Leucania Straminea.—Clevedon, J. M.
Nonagra Despecta.—Clevedon, J. M. The only record from Somerset, and only one previous record in the district.
Nonagra Geminipuncta.—Clevedon, J. M. Mr. Crotch used to find the larva not rare in stems of reed near Weston-super-Mare.
Xylophasia Scolopacina.—Clevedon, J. M.
Luperma Cespitis.—Clevedon, J. M.
Mamestra Abjecta.—Seven specimens, by myself on the sand-hills near Weston-super-Mare in 1893, likely to be passed over as faded specimens of M. Brassicæ, unless very carefully looked at.
Agrotis Cinerea.—Clevedon, Mr. Mason. The only record from Somerset. One specimen, May, 1893, at Dursley, by Mr. Bartlett.
Noctua Rhomboidea.—This species, marked as doubtful in Mr. Hudd's list, occurs at Dursley and in the woods round Wotton, and used to be taken not uncommonly at sugar by the late Mr. Phillips.
Xanthia Gilvago.—Clevedon, Mr. Mason, in 1885. An interesting addition, quite new to the district.
X. Gilvago.—Stonehouse, Mr. Nash, entomologist, January, 1896.
Dianthecia Conspersa.—Clevedon, J. M.
Polia Chi.—Clevedon, J. M., 1884. Another species not previously met with in the Bristol area.
Epunda Lichinea.—Clevedon, J. M.
Hadena Contigua.—Clevedon, J. M. The only Somersetshire record.
Cucullia Chamomillæ.—Downing, Mr. R. Mayes; Fishponds, by myself; Clevedon, Mr. Mason. No previous Somerset record.
Heliothis Peltigera.—Clevedon, J. M., 1884.
Heliothis Armigera.—Clevedon, J. M., 1885 and 1888.
Plusia Festucæ.—Easton, Mr. O. Hunt; Clevedon, J. M. Mr. Hunt's capture being the only Gloucestershire record.
Toxocampa Pastinum.—Clevedon, J. M.

DELTOIDES.

Paraponyx Stratiotalis.—Clevedon, J. M.
Botys Lancealis.—Clevedon, J. M.

Mecyna Polygonalis.—Clevedon, J. M. One of the most interesting of Mr. Mason's captures. New to the district.

Scoparia Resinalis.—Clevedon, J. M., in old apple orchards. First record from Somersetshire.

Scoparia Truncicolella.—Walton Moor, J. M. Only record in Somerset.

Homœosoma Binævella.—Clevedon, J. M. Only record in Somerset.

Homœovella Sinuella.—Clevedon, J. M. Another addition to the list; no previous record in the district.

TORTRICINA.

Halias Chlorana.—Walton Moor, Mr. Mason; Ashcott, by myself. A species new to the district.

Peronia Aspersana.—Clevedon, J. M. First record in Somerset.

Orthotænia Antiquana.—Clevedon, J. M. First record in Somerset.

Phtheochroa Rugosana.—Clevedon, J. M.

Sciaphila Chrysantheana.—Clevedon, J. M.

Poedisca Ophthalmicana.—Clevedon, J. M. First record in Somerset.

Ephippiphora Populana.—Clevedon, J. M.

Retina Turionana.—Clevedon, J. M. New to the district; an interesting addition to the list.

Stigmonota Regiana.—Clevedon, J. M. Only record from Somerset.

Dichorampha Plumbana.—Clevedon, J. M. Only record from Somerset.

Caloptria Aspidiscana.—Clevedon, J. M. Only record from Somerset.

Argyrolepia Cnicana.—Clevedon, J. M. A species new to the district.

It will be thus seen that two reputed species have been established as occurring in the Bristol district—viz., Setina Irorolla and Noctua Rhomboidea. One species previously recorded just outside the bounds of the district has been taken near Bristol. I refer to Nyssia Hispidaria.

Nine species altogether new have been added to the list—viz., Nudaria Senex, Lobophora Sexalisata, Xanthia Gilvago, Polia Chi, Mecyna Polygonalis, Homœosoma Sinuella, Halias Chlorana, Retina Turionana and Argyrolepira Cnicana.

Two species that had previously been found in Somerset have been taken on the Gloucestershire side of Bristol;

while eighteen, hitherto only recorded from the Gloucestershire side, have been found in Somerset.

Hesperus Actæon, Abraxas Pantaria, Coremia Quadrifasciata, Phibalapteryx Polygrammata, Pionia Margaritalis, and Homœosoma Nimbella are all, I think, species that have never occurred near Bristol, and should be taken out of the list altogether.

Melanippe Hastata was, I feel sure, taken several times at Dursley by Mr. Phillips. I also remember a record many years ago of the occurrence of Stilba Anomala in the woods near Weston-super-Mare. Thera Simulata, a reputed species, may probably turn up in the valleys near Stroud, where its food-plant, the juniper, occurs commonly.

Noctua Dahlii, given in Stanton's Manual as occurring at Bristol, is considered by many entomologists as only a variety of Noctua Festiva; and additional evidence of the occurrence of Thecla Betulæ and Pruni, and several other species, is required to establish their right to be considered Bristol species.

Natural History Notes.

ORNITHOLOGY.

On the Occurrence of the Hawfinch (*Coccothraustes vulgaris*) on and around Brandon Hill.

A FEW of these birds may be found every year, when the hawthorn is in berry, on Durdham Down and Brandon Hill; but this winter, owing, I presume, to the scarcity of their food, through the pretty general failure of the hawthorn fruit, many have congregated on and near Brandon Hill, where the trees have a considerable number of berries on them. Any one crossing the hill may see specimens any day, and at almost any time of the day, by walking quietly among the trees and keeping a stealthy watch for them. The birds are exceedingly shy, and if you stop in your walk to look at them, they at once take flight; but if you pass along as if not noticing them, they feed on unconcernedly.

I have had abundant opportunities of watching these birds, as one or more have been feeding every day through the winter in a tree close to the windows of my house at Bellevue, Clifton. They sit very quietly in the tree, only moving now and then to pick a berry, which by a slight movement of the beak is stripped of its flesh, which falls to the ground; the stone of the fruit is then held for a second or two in the beak, of which you see a slight movement when the two sides of the stone are seen to fall, the kernel of the fruit being the only part eaten; the bird then reaches for another berry, when the same proceedings are repeated. Occasionally they descend to the ground, and may be seen hopping about with chaffinches and other birds.

During the winter months they seem very solitary feeding alone. Should one attempt to alight upon a tree on which another is feeding, a battle is at once commenced, and the vanquished bird is obliged to seek its food elsewhere. I have only once, during the winter, seen two birds feeding on the same tree at one time, and in this case it only lasted a few minutes, when one had notice to quit.

A pair of hawfinches bred at Fishponds in 1894, bringing up one or more broods, and again during the last summer the same, or another pair, brought up a nest of young ones at the same place. The nest, which was loose in texture, was placed in the branches of a pear tree, and was not noticed until the young were fully fledged. I also know of several other nests having been found around Bristol.

I once kept a hawfinch for a year or two. As a cage bird it is not interesting, its time seeming to be divided between eating and sleeping. It had a note or two, which could scarcely be called a song. It was exceedingly fond of cherry and small plum-stones; these it would cleverly open for the sake of the kernels inside, which it greedily devoured.

George Harding.

Curious Capture of a Moorhen (*Gallinula chloropus*).

On September 27th, 1894, I accompanied a friend on a pike-fishing expedition in the neighbourhood of Puxton, Somerset. Having arrived at the piece of water where we intended to "try our luck," my friend remarked, "Just the place to find a moorhen, isn't it?" "Well," I replied, "I shall be surprised if we see one all day." We then separated in order to fish the opposite end of the water. We may have had one or two bites when I heard him call out, and looking up I saw him with a black-looking object dangling from his hand. He describes what happened as follows:—

"I noticed a slight movement amongst a mass of weeds floating near the margin of the water; at one point something seemed to rise from below, pushing up the weeds with it, and then to subside a little. Thinking this might be a fish, I cautiously placed my hand over the slightly projecting mass, and then by a quick movement seized hold of something beneath. On withdrawing my hand, I found I had caught a living moorhen by the head."

At first the bird was quite passive and appeared to be half-tame; it soon, however, began to struggle, using its strong legs very effectively. It was placed in a fishing-basket and brought home. Although a very comfortable run was made for the bird in the garden, with a pan of water sunk in the ground and suitable food provided, I regret to say that the moorhen died a few days after its capture. It seems to me that the circumstances attending its capture illustrate a method of concealment frequently adopted by birds of this class. On approach of danger the moorhen is seen to dive, and is then lost to sight. May it not be in many cases that the bird has risen to the surface under a mass of floating weeds, where it remains with its head just above the water, but concealed under a canopy of stems and leaves, being thus able to breathe freely and perhaps to watch until the source of alarm has vanished. It seems probable, moreover, that frequent repetition of such a performance would give a bird such confidence in its safety that it would allow itself not only to be closely approached, but even to be touched, remaining all the while perfectly motionless.

CLAUD F. DRUITT.

NOTE ON THE NIGHTJAR

(*Caprimulgus Europæus*).

I was much interested on May 18th to find a nightjar resting on a rock at Cadbury Camp, on which he has rested now, during the daytime, for three summers. I saw him there several times last year, and took friends to see him. His plumage adapts itself very well to the rock, and the bird is quite hard to see at first.

HERBERT C. PLAYNE.

NOTE ON THE SPRING MIGRATION OF 1896.

The spring migration has been, I think, instructive this year. A wave of cold passed westwards over central Europe about the equinox, and its effects on the "passage" were interesting.

The four species which come earliest to our shores—the wheatear, chiffchaff, willow wren, and blackcap—were here unusually early, by the 25th of March,—that is before the cold wave had proceeded far. Doubtless many of their kin were detained, but still they were here in fair numbers and in good condition, judging from the way they set about singing at once, by that date. Then came a long interval during which no more arrivals appeared. Finally, however, several days late, the rest of the migrants appeared. The cold wave was travelling westward, from newspaper accounts. Consequently the eastern route across the Continent from Asia Minor was opened soonest, and the nightingale—a truly eastern route traveller—came quite punctually, and began nesting earlier even than usual. The most unpunctual arrivals were certainly the corncrakes and the spotted flycatchers—fully a fortnight late—and these are western route birds, at least they are among the commonest of the few migrants which find their way to Ireland.

A feature this year is the extraordinary late nesting of the chiffchaff. The nightingale had a full clutch before I could find a chiffchaff's. I think the hen chiffchaffs must have been caught on passage, and badly handled by the cold.

D. T. PRICE.

ENTOMOLOGY.

A NEW BAIT FOR MOTHS.

ON September 22nd, 1894, Mr. R. M. Prideaux and the writer sugared for moths in Steyne Wood, Bembridge, Isle of Wight. As on many other occasions during this most disappointing season, our sugar proved unattractive, none of the patches being visited by even a single moth.

On leaving the wood, however, a *Phlogophora meticulosa* flew out from a hedge, and on Mr. Prideaux turning his lamp in that direction, he found that a pile of dead hawthorn branches, trimmed from the trees and left at the hedge-side to wither, was covered with moths. These branches were smelling strongly with the peculiar scent of decaying leaves, and were very wet, as drenching showers had fallen at intervals during the day. All the insects were eagerly sucking up the moisture, which no doubt was sweetened by some saccharine product formed in the process of decay. The number of moths found upon this heap of clippings must have been at least twenty, and they consisted of six species, of which the pretty *Xanthia Silago* was the most numerous. The attractive power was not confined to this particular pile of dead branches, as we found moths on several similar heaps elsewhere in the hedge; neither was it restricted to decayed hawthorn alone, as we found some specimens on maple leaves. It seems likely that entomologists may find it worth while to examine decaying boughs in showery weather, or to place such boughs in suitable positions with a view to attract moths.

GEO. C. GRIFFITHS.

Colias Edusa, VAR. *Helice*, ON CLIFTON DOWN.

It may be of interest to record that a fine specimen of *Colias Edusa*, var. *Helice*, was captured on Clifton Down by Mr. G. C. Thompson on September 29th, 1894. In Mr. A. E. Hudd's list of the Lepidoptera of the Bristol District, the first instalment of which appeared in the Proceedings of this Society in 1877, this variety is stated not to have occurred in Gloucestershire, and I am not aware that any capture has since been recorded until the one above mentioned.

GEO. C. GRIFFITHS.

ABSTRACT OF PAPER ON THE GENUS *Coronis*.

The genus *Coronis* belongs to the *Uraniidæ*, which have been placed by various authors, by turns, in nearly all the divisions of the order Lepidoptera, but are now generally considered to belong to the *Bombycidæ*, to which group Westwood referred them in his monograph published in Trans. Zoo. Society for 1878.

The range of *Coronis* is from Brazil to Central America and Mexico, and one species extends into the West Indies. The number of species is about twenty-five.

The larva is bombycid in many of its characters, and the pupa is enclosed in a loose cocoon spun at the base of a folded leaf.

Attention was called to the divergence in coloration of some of the genus from the others, some having blue, and the remainder with red or fuscous markings. It was also stated that the red species lacked certain sexual marks found in the blue species, also that the latter, apparently alone amongst the Lepidoptera, possessed pectinated antennæ in the *female*, and simple antennæ in the *male*. This was noticed by Westwood in *C. erecthea* and *C. boreada*, and is now confirmed by the writer in *C. hysudrus* and *C. orithea*.

It was suggested that, in these species, the female carries on the courtship (as in certain birds), and that the structural differences found in the blue section entitled it to generic rank.

GEO. C. GRIFFITHS.

THE ENTOMOLOGICAL SEASON OF 1894.

The season of 1894 opened with good promise, and owing to the favourable weather of the early spring, many of the first records compare well with the remarkable season of 1893. The cold winds which set in during April, however, and the subsequent low temperature and sunless character of the summer, soon had their effect on insect life, and the season, as a whole, has been the most barren and disappointing one in my remembrance.

Not a single imago of our local hook-tip, *Drepana sicula*, was taken during the summer. Mr. C. Bartlett was fortunate enough to find one larva, but that is the sole record of this interesting insect for 1894.

GEO. C. GRIFFITHS.

THE ENTOMOLOGICAL SEASON OF 1895.

The unusually severe and prolonged frost which began in January, 1895, and continued without a break until the early part of March, had the effect of delaying the emergence of the early spring moths. Sallows were very late in coming into flower, and sallow-haunting species, such as the genus *Tæniocampa*, were equally tardy in their emergence. *Brephos parthenias* and *Diurnea fagella* also were from a fortnight to three weeks later than their average dates.

With the latter end of March, however, a season of abnormally warm weather set in, which gradually brought the dates of emergence of insects and blossoming of flowers more into line with those of other seasons, so that by the end of May there was but little divergence from the average.

The remainder of the year calls for no special notice; butterflies were perhaps less numerous than in some seasons, and no notable entomological captures were recorded in this district.

Our local hook-tip, *Drepana sicula*, was not seen in the imago state, its emergence being possibly overlooked in consequence of the disarrangement of dates caused by the unusual spring, but five larvæ in all were obtained in the autumn by three local collectors.

GEO. C. GRIFFITHS, F.Z.S.

Reports of Meetings.

GENERAL.

THE most important event in the past session has been the alteration of the date of the annual meeting from May to January. The resolution to this effect was carried at the March meeting, 1895, but the officers whose duties should have terminated at the May meeting, were requested to continue their services till the January meeting of 1896. Owing to this change the present part of the Proceedings contains a record of meetings from October 4th, 1894, to December 5th, 1895. During this period eleven general meetings took place.

On October 4th, 1894, Dr. A. B. Prowse read a paper, entitled "Some Ancient British Remains near Long Ashton" (Somerset). The paper was illustrated by maps and photographs. At the same meeting, Mr. Claud Druitt narrated a remarkable capture of a moorhen, Mr. J. F. Perry exhibited the tympanic bone of a whale, and Dr. J. A. Norton some birds' eggs.

On November 1st Professor A. P. Chattock gave a lecture on "The Elasticity of Water," illustrating it by means of experiments and blackboard drawings.

On February 7th Dr. J. A. Norton read a paper, called "Facts and Fancies from the Note-book of a City Naturalist." Mr. H. C. Playne exhibited a marsh warbler's nest found in the neighbourhood, and Mr. H. J. Charbonnier a specimen of Sabine's snipe.

The meeting on March 7th was devoted to a paper by Mr. Cedric Bucknall, on " A Botanical Ramble in Switzerland." The paper was illustrated with lantern slides.

On April 5th two short papers were read, the first by Dr. A. C. Fryer, on " Some Bookworms found in America " ; the second by Mr. R. B. Webb, entitled, " Our Fields and Hedgerows."

On May 2nd the President, Dr. S. Young, gave a lecture on " The Liquefaction of Gases." The lecture was profusely illustrated by experiments.

The meeting on October 3rd was occupied by Mr. H. C. Playne, who read a paper on " Summer Visitors to the Neighbourhood of Bristol." The paper included many interesting personal observations.

On March 7th Mr. S. H. Reynolds read a paper, entitled "The Horse and its Allies," illustrating it by means of lantern slides.

The last meeting of the session was held on December 5th, when Mr. W. A. Shenstone read a paper on " Pasteur's Life-work." The paper was illustrated by slides and an exhibition of apparatus.

The papers by Mr. Playne, and Drs. Fryer, Norton and Prowse, will be found printed in the present number of the Proceedings.

All the meetings took place at University College.

BIOLOGICAL SECTION.

THE District Flora has been further investigated by some active botanists, who have made several discoveries during the past year. *Cerastium arvense* and *Rubus sulcatus*, both new to the county of Somerset, have been found :—the former by Mrs. Gregory, on the Mendips, and the latter by Mr. David Fry, near Compton Dando; while Mr. Miller has confirmed an old record for the rare *Vaccinium Oxycoccos.*

JAS. W. WHITE.

GEOLOGICAL SECTION.

THE work done in the Geological Section during the last two years has been very limited. The number of members in the Section is practically stationary. During 1895 Mr. James D. Marshall, a member of the Bristol Geologists' Association, read two papers on British Brachiopoda, his papers being illustrated by a unique collection of fossils.

The first of these papers had to be postponed from 1894 on account of Mr. Marshall's illness. The second of the papers was supplementary to the first one. Both papers will be found published in full in the accompanying volume.

At the first Annual Meeting for 1896, held at University College, on March 25th, the accounts and expenditure for the Sessions 1894–1895, together with the Annual Report, were presented and passed, and the officers re-elected.

The Hon. Secretary referred to the loss the Section had sustained in the death of Mr. Charles Richardson, M. Inst. C.E., past President of the Bristol Naturalists' Society, who for many years regularly attended the Sectional meeting.

On the motion of Professor Lloyd Morgan, in the absence of the President, Mr. A. Capper Pass, it was carried unanimously that the Hon. Sec. should draft and forward to Mrs. Richardson a letter of condolence and sympathy with herself and family in their bereavement; this letter was subsequently forwarded.

Efforts consequent upon various proposals and suggestions which had been brought forward since the date of the last report with a view to affiliate members of the Bristol Geologists' Association and members of other bodies doing similar work, on the payment of the Sectional fee only, had after much discussion to be abandoned, as it was found this object could not be obtained without inflicting injustice upon members and associates of the parent Society, and without injury to the funds.

The Hon. Sec. has had great difficulty in securing papers, or promises of papers, and urges members of the Section, if they wish to have more numerous Meetings, either to contribute papers themselves or to forward to the Hon. Sec. the names of friends willing to do so. This difficulty is not confined to the Geological Section of the Bristol Naturalists' Society, but is none the less deplorable. The Hon. Sec. is, however, glad to be able to announce promises of two papers for the winter.

A. WHARTON METCALFE, *Hon. Sec.*

PHYSICAL AND CHEMICAL SECTION.

DURING the session five meetings have been held at University College, an average of 12 members and visitors being present.

Eleven new members have been elected—5 ordinary, 1 sectional, and 5 sectional associate members respectively.

The total number of members is now 45.

The following communications were made :—

"The Formation of Hydrogen Peroxide in Organic Compounds under the Influence of Light and Oxygen."—Dr. Richardson.

"An Account and Exhibition of the Fleuss Pump."—Mr. W. A. Shenstone, F.I.C.

"The Action of Natural Waters in Modifying the Bactericidal Power of Sunlight."—Mr. F. W. Stoddart, F.I.C.

"An Electrically maintained Clock for Continuous Records."—Mr. R. C. Clinker.

"The Spectrum Top."—Mr. D. Rintoul, M.A.

"An Early Form of Oil Valve Pump."—Mr. P. Jolin.

"A Modified Hofmann's Apparatus for Vapour Densities."

"Two Forms of Apparatus for Fractional Distillation, one with Dephlegmator, and the other with Constant Temperature Still-head."—Dr. Young, F.R.S., and Mr. G. L. Thomas, B.Sc.

CHARLES R. BECK, F.I.C., *Hon. Sec.*

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PROCEEDINGS

OF THE

BRISTOL NATURALISTS' SOCIETY.

EDITED BY THE HONORARY SECRETARY.

"*Rerum cognoscere causas.*"—VIRGIL.

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NEW SERIES. VOL. VIII., PART II.

On Some Lepidopterous Larvæ:

THEIR HABITS AND MEANS OF PROTECTION.

By G. C. GRIFFITHS, F.Z.S., F.E.S.

(*Read May 7th*, 1896.)

WHILE we are all constrained to admire the butterflies with their sun-loving habits, and their fondness for the flowers and the breezy downs, so that to miss them from our country walk would be to lose one of the most potent charms of the summer-time; yet, apart from the professed entomologists present, there are probably few who regard with any amount of toleration the larvæ, or caterpillars, from which our butterflies and moths proceed. Nasty creeping things they are termed by many, and those of us who have greenhouses well know the amount of damage which can be done by one or two nocturnal feeding larvæ, hiding perhaps beneath the surface of the soil during the day, but coming forth in the darkness to feed on the foliage of the plants we have tended with such care.

Yet these destructive creatures, which we class amongst vermin and destroy, have many interesting habits well worthy of our study, and a consideration of them may teach us much which would be hidden from those who only observe the perfect moth or butterfly.

The business of the larva or caterpillar is to feed and grow, to build up a supply of energy which shall carry it through the long pupal sleep and equip the perfect insect with the strength to guide its rapidly moving wings through the air. In some of our most powerfully flying insects the mouth-parts are so imperfectly developed (as in our Oak Eggar or Fox Moths) that no food is taken in the imago or winged state, consequently the organism has to depend on the stored-up energy inherited from the days of its larval growth. But as the larva has so much work to do, a voracious appetite constantly requiring food, it is generally slow in its motions, and in many cases scarcely moves at all, whilst its supply of leaf-food remains unexhausted. Hence in this stage, usually of long duration, it is always more or less open to attack by the great enemies of the lepidoptera —the birds.

Their bright eyes are constantly on the watch, and the poor larva once detected is soon seized by the sharp bill of its dreaded foe. Thus, were the larvæ not protected from their enemies in manifold ways, even the vastly prolific races of the insects would soon dwindle under the persistent attacks of their destroyers. Yet such are the beautiful and varied devices by which caterpillars are protected during the stage of insect life most marked by danger, that it is rarely that the equilibrium of Nature is greatly disturbed.

Where species are becoming rare or have entirely disappeared in England, the cause generally lies in some act of man or modern civilization, which has altered the face of the country or destroyed the food-plant of the insect. Of this we have a notable instance in the drainage of the Fens of our eastern counties, which has led to the total extermination of our Large Copper Butterfly, and the disappearance from England of *Lœlia Cœnosa* and other insects.

On the other hand, when favourable natural causes have produced an unusual abundance of any species, it is often found that this very abundance attracts fresh enemies, either mammals, birds, or parasitic insects, which speedily reduce the numbers of the larvæ to the normal point; in fact a year marked by vast swarms of any particular species is often followed by a season of scarcity. Of course where we, by a wanton and excessive destruction of bird-life, have destroyed the balance of Nature, we have only ourselves to thank if garden and orchard are infested by hordes of predatory larvæ.

I may here observe that I have thought it better not to deal with the lepidopterous larvæ, which I wish to speak of to-night, in the usually classified order, which is, by the way, just now threatened with a far-reaching and revolutionary change, based in great measure upon the pupal characters. With such a difficult subject we have nothing to do to-night; it is quite outside our field of view—the larva.

I have therefore broadly grouped the larvæ according to their ways and means of protection, as these will be found to be closely correlated with their habits, and at the same time this grouping fits in sufficiently well with the generally received classification.

One of the most usual means by which the larvæ of moths are protected is by resemblance to twigs or branches, or by the similarity of their colour to the leaves on which they feed. The great family of Geometers, Land Measurers, or Measuring Worms, as they are called in America, from their singular means of progression, or looper caterpillars as we sometimes call them, are instances for the most part of protection by resemblance to twigs. These caterpillars, long and slender as a rule, rest motionless for considerable periods with their bodies at an angle from the branch to which they adhere by their hind claspers, the great strain caused by assuming this attitude being met by their spinning a thread of silk, one end of which is attached to the branch whilst the other is held by the larva. In this way they nearly always rest when not feeding, and the resemblance to a twig is often so complete as to deceive even a careful searcher.

To add to their great general resemblance to twigs, the bodies of these caterpillars are often diversified by rough warty humps or excrescences, whilst their colour is usually of some shade of brown grey or green. The larva of the large Emerald Moth (*Geometra papilionaria*) resembles the catkins of the birch trees on which it feeds, and is either green or brown, two colours which are represented by the catkins of the tree in their younger or more advanced stages.

Next we have the larva of a South American butterfly belonging to the Nymphaline genus, *Anæa*, described by Wilhelm Muller, which makes its surroundings resemble itself. In feeding it leaves certain irregular pieces of leaf attached to the mid-rib by little stalks; these in some degree bear a resemblance to the body of the larva, which is green above and dark beneath, and which has considerable likeness to a piece of irregularly eaten leaf.

On one occasion I had the pleasure of rearing a dozen caterpillars of *Macroglossa fuciformis*, which I fed upon a plant of honeysuckle growing in a pot in a large larva-breeding cage. These pretty bright green larvæ closely resembled the smaller longitudinally folded leaves of their food-plant, and it was only with the greatest difficulty that they could be seen, though the larva apart from the leaves was decidedly conspicuous. I often used to amuse myself by trying to count them, and it was very seldom that I could see more than eight or nine without an exhaustive search. When full-fed, and the time for pupation drew nigh, the bright green tint of the larva quickly changed to a deep purple brown, and the creature soon descended from the plant to conceal itself in the earth, crawling on which its newly acquired tint gave it the most perfect protection. This singular colour-change occurs in several of the hawk-moth larvæ, but in none that I am acquainted with is it quite so extreme as in *fuciformis*. One of the other species which changes colour in this way is the large and handsome larva so well known to most of us, the caterpillar of the Privet Hawk Moth (*Sphinx ligustri*). This larva, with its bright apple green colour, with seven side stripes of purple and white, and with its head held aloft in the characteristic sphinx-like attitude of the group, is a most beautiful object when seen on a privet or laurustinus bush in the sunlight, yet it is singular to notice how well it is often concealed, notwithstanding its great size and striking coloration. If we withdraw a little from the bush where it rests, we see that the purple stripes break up the mass of the green, and give crossing shadows, thus making the larva appear like the small green leaves of the privet. We may walk past it many times and not suspect its presence, whilst all the while it is resting near the end of a twig without any attempt at concealment.

The larvæ of the great group of Hawk Moths nearly all possess a caudal horn; which in the larva of the Privet Hawk Moth, when it emerges from the egg, is of great size, nearly as long as the body, but after each skin-change it grows relatively shorter. This holds good in a large number of species. The Pine Hawk Moth (*Sph. pinastri*) has it very largely developed in the young larva, and strongly forked at the end, whilst it becomes single and proportionately shorter before the larva has completed its growth. This forked character of the horn in some of the young larvæ shows the relationship of the sphinx moths to the great group of *Bombyces*, for the young larva of *Aglia tau* also possesses a forked horn in the same position. In the spirit specimen of a larva from Buenos Ayres which I have, and for which I am indebted to the kindness of Mr. Charbonnier, it will be seen that there is no horn, but simply a round mark. If we could examine the young larva of this species, I have no doubt we should see a well-developed horn. The larva appears to belong to the genus *Philampelus*, and I find that the young caterpillars of several species of this genus possess it, whilst the full-grown ones are hornless. As the life of the individual larva is a short compendium of the history of the species, we gather that the horn of the Sphinges is a disappearing organ, gradually suffering elimination. Another remarkable species of the Hawk Moth group which shows strong relationship to *Bombyx* is *Ceratomia amyntor*, an American moth, the front segments of which bear four prominences or horns, clearly analogous to the species of some of the larger silk moths. The moth is common in America, and I have several times endeavoured to obtain eggs from there, but in vain up to the present time. I am certain that if this species were reared from the egg, its earlier stages would have a tale to tell of no common interest with regard to the ancestry of the Hawk Moths.

Another very striking larva which I have on two occasions reared from the egg, only unfortunately to lose nearly all my specimens when full grown, is *Endromis versicolora*, the Kentish Glory Moth. This, though a Bombyx, has a larva very sphinx-like in attitude, and with side stripes, though these go in the opposite direction to the stripes of the Hawk Moths. The larvæ, when about one-third grown, have a queer habit of crawling to the end of the birch twig, when perhaps half a dozen will surround it and hang down together like a tassel, with their heads slightly thrown back, looking like a bunch of catkins or small half-opened leaves.

The larvæ of that singular group of moths, the *Sesias*, or Clearwings, and some others, feed internally in the wood of trees, or at least inside the bark. As may be expected from this habit they resemble in appearance maggots or the larvæ of beetles rather than Lepidopterous caterpillars, their jaws being strongly developed, whilst the legs are short, and the prolegs or claspers almost rudimentary. Dwelling as they do in dark galleries eaten out in the wood, they are protected from many enemies, yet not from all, for some of their insect foes are provided with means of searching them out even as they lie concealed. On one occasion I was looking for larvæ of the Apple Clearwing (*Sesia myopæformis*) in the bark of an old tree in a garden at Guildford, which was honeycombed by the tunnels of many generations. Presently I became aware that I was not the only searcher for the hidden larvæ. A small ichneumon fly was busily running up and down the trunk, working its antennæ constantly backwards and forwards. On finding a hole which it believed was occupied by a larva, it would dart down into it a long filament from its ovipositor, and if the search proved successful the ovipositor itself would be inserted, to lay within the body of the hapless grub the egg of its destroyer. After watching the process for some time I boxed the ichneumon, lest it should fly away. I now exhibit it as a memento of the tragic struggle for existence which is constantly being enacted in Nature—an insect remarkably well protected from the general perils to which most larvæ are exposed, falling a victim to another which is specialized for the express purpose of preying upon it. These little *Sesias* or Clearwings are very seldom seen or recognised, as they so closely resemble flies and wasps as to be easily passed over; but the larvæ of some of the species are very abundant in certain localities, notably the Currant Clear-wing, which inhabits the twigs of most old currant bushes.

Any damage of which these larvæ may be guilty is quite eclipsed by that which is done to trees by the great larvæ of *Cossus ligniperda* (the Goat Moth), *Zeuzera pyrina* (the Wood Leopard Moth), and others. The first mentioned has caused the destruction of many fine trees, nearly all our forest and fruit trees being liable to its attacks. Its formidable jaws enable it to penetrate very hard wood, whilst its long course of .existence in the larval state, between three and four years, causes the damage done by each individual caterpillar to be very considerable. In some cases seventy or eighty living larvæ have been found in one tree, and when this occurs the powerful goat-like smell of the larva, which has earned for it its English name, is very noticeable. There is a story, believed by Barrett to be authentic, of a goat-moth larva which was shut up in a wooden cigar-box and placed inadvertently on a piano, being found inside the instrument next morning; a clean-cut hole through box and piano showing the path which the larva had taken. It was at one time believed that this caterpillar was the Cossus. of the Romans, and was eaten by them as a delicacy: this belief has given the generic name of Cossus to the insect. It is now generally held, however, that the Roman Cossus was the grub of a large beetle, and it certainly seems only charitable to the Romans to acquit them of fondness for such unsavoury food as the larva of the malodorous Goat Moth. The caterpillar of the Wood Leopard Moth also infests many of our trees, and is believed to have caused the death of numerous valuable elms, not to mention fruit-trees. The moth is always uncommon, but the larva at times abounds, and feeds for two or three years within the wood. Happily the wood-peckers seem to know how to reach these destructive creatures and keep them within bounds. Here the larva of the common yellow underwing moth may be mentioned, considered by Miss Ormerod one of our destructive insects, and the caterpillar is certainly almost omnivorous, and does great damage to garden produce.

In striking contrast to the larvæ which resemble twigs, or those which spend their lives hidden in the interior of tree-trunks or roots, we now have to notice a considerable group of caterpillars, many of them of large size, belonging to the *Bombycina* and *Bombyciform noctuæ* which feed quite exposed, often without the least attempt at concealment, yet are well armed against the attacks of bird or lizard, or the small predatory mammals. I refer to those which are protected by a dense covering of hairs or thorns. If we pass along by a hawthorn hedge or a dog-rose bush in May, we often find a red and black larva with grotesque tufts of hair exhibiting itself conspicuously upon the twigs or leaves. This is the larva of the pretty White Gold-tailed Moth, *Porthesia auriflua*, and a very handsome creature it is; but beware how you touch it, for it bears the worst of reputations. It is covered with very brittle hairs, loosely adhering to the skin, and serrated all along their length with sharp barbs, which remind one of the hideous spears we see in museums, used by some of the Polynesian tribes. These hairs, excessively fine, break off at the slightest touch, and entering into the skin cause an intolerable irritation resembling nettle-rash. I have twice suffered from incautiously handling this species—once from touching the larva itself, and the second time from pulling down with my fingers some old cocoons in the corner of a breeding-cage. It has been supposed that the larva ejects an acrid fluid from certain glands at the root of the tufts of hair, and that this is the cause of the irritation. That it has these glands I have no doubt, as they occur in several species, and in some cases also in the imago, but this will not account for the effect produced by hairs woven into a cocoon months or years old: a glance at the hairs under a microscope will convince any one of their formidable character, and that they are quite sufficient to produce irritating results.

This unpleasant form of protection is shared by many other species, such as the Tiger Moths, the familiar Woolly-bear being a very good instance. We may also note the Scarlet Tiger Moth and the Jersey Tiger Moth. The fauna of the Channel Islands contains many insects which do not occur in England, and until recent years the Jersey Tiger Moth was one of these; but it now appears to have quite established itself in South Devon, and is found there in some numbers every year. The Oak Eggar (*L. quercus*) larva is another instance of protection by means of abundant hairs. It feeds on bramble, and quite exposed to view. So also is the larva of the common Vapourer Moth, which sometimes infests apple and other fruit trees to a great extent. This is remarkable for the great tufts of hair borne by the adult caterpillar, very loosely attached, so that an aggressive bird which pecked at the larva would be certain to fill its beak with a host of dry and prickly hairs, sharp as needles and intensely irritating. The female moth of this, as in a few other species, is destitute of wings, and never stirs from the cocoon from which she has emerged, but lays her eggs upon it. Following Miss Ormerod's illustration of this, I am pleased to be able to show a portrait of a young larva kindly lent me by Mr. Charbonnier. Here it will be seen that the body is pretty evenly covered with hairs: the large tufts of the full-grown larva have not yet been developed.

At the February meeting of the Entomological Society of London attention was called to an instance in which the eye of a boy was affected by inflammation caused by the hairs of *L. rubi*, the Fox Moth. It was stated that the attack recurred after an interval of nineteen weeks, and that in several Continental cases this recurrence had been found to take place, and in some instances permanent injury to the eye had followed. Mr. Blandford mentioned that certain caterpillars had hairs of two kinds, some of them being barbed; and I may say that my own microscopic examination of the hairs of *L. rubi* confirms this. Mr. Blandford said that the number of barbed hairs on a larva of *B. processionea* had been estimated at 720,000. He further stated that there was no evidence of poison glands, and that the property of the hairs was purely mechanical, experiments carried out by Staff-Surgeon Lübbert appearing to be conclusive. In the present instance two hairs were extracted from the eyelid of the patient. Some of the cases of injury recorded on the Continent have arisen from children thoughtlessly throwing the caterpillars at one another.

A hint may here be given to any one commencing an entomological collection never to touch caterpillars, whether hairy or otherwise, with the hand at all; you thus avoid all risk arising from the unpleasant properties of these hairs, and obviate any possible injury to the larva from the touch of the hand. It must never be forgotten that a caterpillar's cylindrical body contains fluid under pressure, and a very slight touch causes it to bleed, and it may be taken as a general rule that a wounded larva is doomed, and never recovers. In the breeding-cages, therefore, they should be disturbed as little as possible. The leaves on which they rest should be cut off with a pair of scissors and laid on the new branches provided for their food, whilst, if they must be moved, they should be gently lifted with a camel's-hair brush.

Numerous experiments have been made at different times with larvæ to ascertain which kinds are eaten by birds and animals and which are distasteful or inedible; and it has been found that these hairy larvæ are in most cases refused, though there are instances where birds have eaten them after carefully rubbing off the hairs. Dr. A. G. Butler mentions the case of a skylark which he tried with hairy larvæ, and which devoured some of them, but died soon afterwards, showing symptoms of acute inflammation; whilst Professor Poulton records that a lizard with which he experimented seized a larva, but relinquished it after biting it for some time. The lizard was evidently greatly irritated by the hairs in its mouth.

Many larvæ also, whether hairy or otherwise, are also protected by possessing a taste which is undoubtedly distasteful to their enemies, and this has been conclusively proved in several series of experiments carefully carried out by Professor Poulton and other observers. In a large number of species this unpleasant property causing immunity of the larva from attack is continued into the perfect state, notably so amongst the Danaidæ, Heliconias, and Acræas, the whole of which appear to be protected by nauseous taste or smell. These are well-known as models, which, under natural selection, are mimicked or imitated by other and edible species. With this, however, we must not deal now, as we are only concerned with the larval stage.

Examining the matter more closely, we find that the larvæ thus protected are almost invariably of bright or conspicuous colour, and usually careless to conceal themselves, often feeding quite exposed, and presenting a striking appearance. Examination has shown that these bright colours are generally arranged in certain prevailing patterns. Thus we have black and white, or black and yellow rings, or longitudinal stripes of black, orange, or red. In fact, if we meet with a caterpillar largely partaking of these colours, or with its coloration arranged in rings or stripes, we may at once, with a great degree of probability, put it down as distasteful, whilst larva of green or brown hue, and protectively marked, is usually edible. As instances of this style of warning colour we may mention the common larva of the Currant Moth (*A. grossulariata*), the Cinnabar larva (*Euchelia jacobæa*), with its black and orange rings, which we find feeding, without any attempt at concealment, on ragwort or groundsel at the beginning of August; the common Buff-tip (*Pygæra bucephala*), which we meet with in large colonies on lime or birch, or some of our other large trees, with its yellow colour marked with black; also the common large white butterfly (*P. brassicæ*) of our kitchen garden. Abroad we have the highly distasteful *Danais Chrysippus*, yellowish white with narrow black stripes, and with six spiny processes on its third, sixth, and twelfth segments. And in the same category come that exceedingly handsome caterpillar, the *Deilephila euphorbiæ* (the Spurge-hawk Moth), *Deilephila galii* and *chamænerii*, *Arcte polygraphica*, *Polytera gloriosa*, and many other exotic species; also at home our Mullein Shark Moth (*Cucullia verbasci*), *Cucullia lychnitis*, the Sword-grass Moth (*Calocampa vetusta*), and the beautiful larva of the Brown Moth (*Hadeni pisi*). In this last species a few individuals have an olive-green ground colour, instead of the rich purple-brown which generally prevails; but as this colour rarely persists into the last stage of the larva, being usually discarded for the brown hue in change of skin when the larva is about half-grown, the green variety is probably the survival of an older coloration now abandoned by the majority of the individuals of the species. Each form bears the longitudinal yellow stripe, and both feed quite exposed and on the upper side of the leaves of broom or bracken, and are evidently distasteful. And this change of colour of a larva when partially grown leads me to speak of the strange change of coloration and habit undergone by the caterpillar of *Acronycta alni*, a moth rather rare in England, but one of the most interesting species to rear which has ever come under my notice. The larva feeds on lime, alder, and other trees, and during the greater part of its life is most sluggish, nearly always resting on the upper side of a leaf with its head bent round touching its side, eating a hole in the middle of the leaf, and being scarcely ever seen in motion. In this peculiar position, with its soft grey and black colouring, it very much resembles excreta dropped by a bird; and to this, no doubt, owes much of its protection, though a close inspection reveals several long hairs with spatulate points, no doubt a warning to any too curious bird to beware of tasting. But at the last skin-change a remarkable metamorphosis occurs—the larva puts on a garb of intense blue-black, with striking yellow patches on the upper side of each segment: the broadly pointed and flattened hairs are still more conspicuous, and the caterpillar appears in full perfection of warning colours. It also at the same time develops a complete change in its habits, and crawls (I had almost said runs) with quite a rapid motion over the foliage. It probably pupates in nature in a crevice of the bark of a tree, or under loose bark, but in captivity will use the interior of a bottle-cork, or a short piece of bramble stem, from which it quickly excavates the pith. When several of these handsome caterpillars are moving about in the breeding-cage, they have a very pretty appearance, and the rustle which they make in traversing the leaves is quite audible. The value of warning colours to the larvæ which possess them is obvious when we remember the fact already mentioned, that a slight wound, the merest peck from a bird or bite from a lizard, is in nearly every case fatal to the delicate organism. Hence the mere distastefulness of the larvæ does not avail the bitten individual, though it will probably make its enemy more cautious in future attacks; but the possession of these conspicuous colours, when the bird has learnt to associate them with an unpleasant taste, must save many a larva from a fatal bite.

The caterpillars of the Large and Small Elephant Moths (*Chœrocampa elpenor* and *Porcellus*), with some others of the sphingidæ, are remarkable for another kind of protection. *C. elpenor* has a large dark-brown or occasionally dark-green larva, which usually hides amongst the dead leaves on the lower parts of the stem of the Great Willow Herb, where it is well guarded by the similarity of its colouring. If the plant is touched, however, the larva instantly draws back its head and three first body segments into the two next rings, when the fore part of its body, of course, appears much swollen, and the four enormous eye-spots on these two segments suddenly become most prominent, and give the creature a truly alarming appearance. It thus resembles the fore part of a snake, the eye-spots, according to Prof. Poulton, giving the effect of the spectacle mark on the cobra's dilated hood. In his book on *The*

Colours of Animals he mentions that he once offered a caterpillar of the Large Elephant Moth to a green lizard, which at first was evidently suspicious, and yet afraid to attack the larva, which placed itself in its terrifying attitude. The lizard kept boldly advancing and then retreating in fright, but at each advance approached a little nearer. At length it ventured to gently bite the head, then swiftly retired; but finding there was no retaliation again advanced and gave a harder bite. At last it appeared satisfied that the whole thing was a fraud, and devoured the larva. He had often given the same lizard equally large hawk-moth caterpillars of other species, which were always doomed without ceremony. He says he never saw a lizard behave with such caution as on this occasion. Prof. Weismann found that fowls were much awed by the appearance of this larva, and that on placing one in a seed-trough, small birds (sparrows and chaffinches) were effectually kept off by it.

If we carefully examine the boughs of black poplar or willow trees in July and August, we may chance to find the large and remarkable larva of the Puss Moth (*Cerura vinula*). This is one of the most grotesque and singular of our larvæ, and is well worthy of our consideration. I regret that it is an exceptionally difficult larva to preserve, and my specimens do not give any idea of the beauty of colour it possesses when living.

On one occasion I had the pleasure of rearing a brood of these caterpillars from the egg, and found them very easy to breed and interesting to observe. The young larvæ are most peculiar objects when they emerge from the egg; deep black, having absurdly long, forked tails, which they carry almost erect; their heads are broad, and have angular points at the sides, almost like pointed ears—in fact, when they drew their tails together, as they sometimes did, they had a ridiculous resemblance to little black cats. As they grew older, and after a skin change or two, their sides become green, whilst the back remains dark. When full grown the larva is mostly green, the patch on the back being of a light purple, sometimes much toned down with white. If disturbed, the larva throws its head back in a kind of sphinx-like attitude, drawing back till the fore part is compressed and swollen, giving great prominence to two black marks resembling eyes, and having the true head surrounded by a livid red margin; thus giving, as Poulton describes it, an intensely exaggerated caricature of a vertebrate face. At the same time the forked tail is erect, and if the creature's body is touched, suddenly and swiftly two pink whips or filaments are protruded from the fork, the tail is still more curved forward, and the whips are shaken over the head. These whips are probably a protection against the attacks of a species of ichneumon fly, to which the caterpillar is very subject. It has still another defence; for if the irritation is continued, the larva may eject a strongly acrid liquid from a gland beneath the head. Prof. Poulton, who has studied this larva most exhaustively, and has published his results both in the *Trans. Ent. Society*, and in his book *The Colours of Animals*, has analysed this liquid, and finds that it is a mixture of formic acid and water: in a mature larva the proportion of acid being as high as 40 per cent., and the twentieth of a gramme can be ejected if the caterpillar has not been irritated for some days. "So far as we know at present," he says, "no other animal secretes a fluid containing anything which approaches this percentage of strong acid." On one occasion a larva, which I found on a tree in Tyndall's Park, ejected its fluid whilst I was trying to box it; fortunately it did not enter my eye, but the liquid is expelled with great force, and flies to some little distance. Mr. Poulton proved by experiment that it had a fatal effect upon the ichneumon fly which attacks the larva, and is therefore a great protection. The ichneumon, if it succeeds in effecting a lodgment, lays its black eggs just behind the head, whence the caterpillar cannot dislodge them, and once laid, the unfortunate creature's fate is sealed.

Another very remarkable caterpillar is that of the Lobster Moth (*Stauropus fagi*), which is rare in England, so that we seldom have the opportunity of observing it. I, on one occasion, however, obtained three larvæ from the New Forest, and found them very curious and interesting creatures. My experience of them began badly, for within a few days of their arrival the largest larva devoured the smallest. The second one was either unhealthy or had been bitten by the other, for it did not thrive, and eventually died; but the large one justified the theory of the survival of the fittest, for it is now in my collection in the perfect state. These larvæ, with their brown colour, strongly resemble the bunches of brown scales which enclose the buds of the beech tree, and hang down after the leaves are expanded. The long bent legs also add greatly to this special resemblance. But if the larva be approached or disturbed, it quickly throws itself into a terrifying attitude, holding the fore part of its body erect, and stretching out its long legs, thus looking like a large spider. The front pair of legs in this resemblance do duty for the jaws of the spider, whilst the other four are made to clutch and quiver in the air, as though the creature was on the point of seizing its prey. The hind part of the body is thrown forward over the head, so that the fork-like appendages at the tail quite project beyond it, giving the larva a most formidable appearance. On the side of the fourth and fifth body-segments are very black patches, which, when the insect is at rest, are quite concealed by a flap of skin. But when the terrifying attitude is assumed, these flaps fall back and reveal the black patches. Hermann Müller has suggested that these marks serve to imitate the appearance of ichneumon stings, so that the ichneumon fly may conclude that the caterpillar has already been attacked and tenanted by one of its race. Prof. Poulton found that these caterpillars were not distasteful, but that they were eaten both by a marmoset and a lizard with which he experimented, though when in their defensive attitude they were only approached by both animals after long examination and with much caution.

I next call attention to some specimens of larvæ of the swallow-tailed butterflies. They are very beautiful, and are remarkable for the peculiar Y-shaped process which they can protrude from behind the head, and which is no doubt an intimidation to their foes.

I have recently referred to cannibalism: for the credit of the larval community, I am pleased to testify that this only occurs in a few species, and close confinement in our breeding-cages may sometimes bring it about when larvæ in freedom in their natural conditions would not be guilty of it. There are one or two species, however, the caterpillars of which are inveterate cannibals. Amongst the worst of them may be mentioned *Cosmia trapezina*; this, if accidentally introduced into the cage, will soon slaughter and devour all its companions. From the way in which it follows up and attacks them, it seems probable that this is not a sudden impulse caused by dry food or confinement in close quarters, but is most likely a characteristic of the larva in its wild state. It devours not only larvæ of different species from itself, but its own brothers and sisters, if smaller and weaker. On one occasion I placed four of these larvæ in a jam-pot together with their food, but in the course of a few days one only remained—the tragedy was manifest!

Far different to this rapacious creature is the beautiful larva of our local Hook-tip (*Drepana sicula*), of which we Bristol entomologists are proud to have the monopoly, as far as Great Britain is concerned, and a few words on this species may therefore be of interest. We will suppose that we have been sufficiently fortunate to obtain a female specimen of the moth from its only locality, Leigh Woods. We have placed her in a glass cylinder with some lime leaves, and she has laid a few oval cream-coloured eggs, carefully affixing them singly to the very edge of the leaf, just in the bottom points of the serrations. The eggs have in the course of forty-eight hours taken on their upper surface a beautiful red bloom, so that they resemble little white-heart cherries. Then after a few days they turn dark-red all over, and soon the tiny caterpillar emerges from its shell, a perfect hook-tip in all its characters, with head and tail raised as it crawls, and of a dark red brown in colour.

Now, the greatest difficulty in rearing this larva begins at once—that is, to persuade it to settle down to its food. It is restless, and wanders about, and will die if not looked after most patiently, picked up with a camel's-hair brush, and put down on a special part of the leaf. And I lost many larvæ before I found where this particular place was situated. I discovered that it preferred to begin to feed either just at the tip or on one of the curves by the side of the leaf-stalk. At first it only eats the upper surface, but after the first skin-change begins to nibble through, cutting a long narrow sinus into the leaf. It always lies on the upper surface, and after once taking to its food, is one of the most delightful larvæ to rear that I know of. In the first place you have got a rarity, and that in itself is a great satisfaction. In the next place it will go on eating as long as any food remains, and it seems to like its leaves rather dry too, being found at large on lime trees, which have rather thick hard leaves, a character in which the species of lime on which it feeds varies considerably. As the larva grows in size it becomes more diversified in colour on the back, until in the last stage it puts on bright yellow and purple-brown hues, which, unfortunately, have rather suffered in the preparation of our specimens. When full-fed it rolls one of the lime leaves together into a little funnel closed at one end, spins a brown silk web over the other end, and within this chamber changes to a chrysalis thickly covered with a white powder, which probably has some protective value.

With this local species I bring my remarks to a conclusion. I am conscious that they are of a scrappy and disconnected character, but my difficulty has been, not to find matter of interest amongst the lepidopterous larvæ, but to choose from the redundant material which we have at hand in this fascinating order of insects well-known and singular species which appear to have special claims to our attention.

Some Wanderings in the North of Finland.

By H. C. PLAYNE, M.A.

(*Read December 3rd,* 1896.)

NO doubt there are many here who know what it is at times to be seized with a burning desire for travel which it is impossible to gratify, and those who do, will know also that some small satisfaction can be obtained by opening an atlas, and planning a journey, even though the chance of ever going that journey seems very small indeed. My holidays are generally too short for such a purpose, but last summer I was lucky enough to be able to accomplish one of the smaller journeys of the numbers that are already planned, and, in addition to this, I was still more fortunate in having as a companion a keen naturalist, Mr. A. F. R. Wollaston.

The country we determined to visit was that part of Finland which stretches from the north of the Gulf of Bothnia to a few miles within the Arctic Circle. It had especial attractions for us, because it is the country in which the famous ornithologist, John Wolley, found so many interesting birds when he discovered the nesting-grounds of the Waxwings, just 40 years ago.

It was on the morning of August 2nd, then, that we awoke to find ourselves at last across an inky north sea and in calm water, steaming through Norwegian fjords, past hills which rose with steep slopes from the water, whose tops were hidden in mist, on our way to Trondhjem. Numbers of Gulls and graceful Arctic Terns kept close to us, and every now and then we had the pleasure of seeing an exciting chase between one of the Terns and Richardson's Skua. The Skuas are pirate gulls which live by pursuing the smaller sea-birds, until they disgorge their last meal, which is at once devoured by the Skua. We were able to see this done several times by the side of the steamer. Wonderful dodging on the part of the Tern was of no avail against the rapid flight of the Skua, who pursued like a black falcon with a curiously shaped tail, of which the middle feathers are much longer than the rest.

Black Guillemots, too, were abundant, with a white patch on the wing and red legs, which you can see as the bird leaves the water when the steamer is almost upon it.

In the afternoon we had another most delightful spectacle to watch. We were steaming steadily up the fjord at about 10 miles an hour, when we saw the backs of some porpoises as they made their way towards us. And then for a time several of these mammals of the sea kept close to the side of the boat, racing along in evident enjoyment of the game. Three of them kept absolutely together, and we could see their noses ploughing through the water side by side, and the glistening white of their bellies. Every now and then one would roll over at the top of the water to renew his supply of air. It was only after some minutes that they were tired of the race and left us.

From Trondhjem we went by rail for some distance by the side of the fjord, looking from the train at hosts of Eider duck on the edge of the water. Presently we climbed steadily up to the watershed, which separates the two countries of Norway and Sweden. There the hills are bare of trees, and patches of snow were to be seen. Now and then, too, the railróad is covered by a wooden structure, which is to keep off the snow in the winter.

We stayed for one afternoon at Storlien, on the watershed, where by the side of a small tarn we could walk within a few yards of two kinds of wading birds, Redshanks and Greenshanks—most graceful and charming creatures to see. The Greenshank, especially, would stalk about slowly among the grass, watching us the while, and ducking his head as if with impatience at our daring to disturb him; and the Redshank kept running about on the leaves of water-lilies, whistling in evident anxiety for young hidden among the reeds and grass.

Then for two days we travelled northwards in the train, near the east coast of Sweden, through country covered with forest; always climbing up or down hill or crossing one of the numerous rivers which run eastwards. Country-people often got into the train to travel short distances, and were interested in trying to exchange a few words with foreigners, while they chewed snuff in large quantities. At last we reached Luleå, a port near the north of the Gulf of Bothnia, where ships take in the rich iron ore which is brought from the mines of Gellivara further north. We went on at once by steamer to Haparanda, at the extreme north of the gulf; and then a short row in a small boat to Torneå brought us on the threshold of the country we wished to see. When first arriving at Torneå one is surprised to find oneself on the west of the large river of the same name, and not on the east of it, where nearly all the maps place the town. We were told, however, that some years ago the river altered its course, and at the present time you can cross from Swedish into Russian territory by a narrow wooden foot-bridge over a marsh where the river used to flow.

It has taken just a week to get from Hull to Torneå, but now we intend to travel more slowly. Early in the morning we start in a little cart, and are ferried across the main stream of the river, and drive at a very slow rate of little more than five miles an hour eastward to the river Kemi. Travelling along these roads is done by stages, averaging ten miles each, and at the inn at the end of each stage, you get a horse and cart and boy to take you the next stage. These carts are curious little vehicles of two wheels, often without springs; and travelling in them over very rough roads is the most uncomfortable I have ever experienced. The horse does not pull by traces fastened to the cart as in England, but by two small pieces of leather pushed through holes in the ends of the shafts, and held there by a stick which is pushed through the leather. Now and then the stick drops out, and you have to stop and cut another; once both sticks fell out at the same time, and then the cart tipped up on end, with the shafts in the air, and deposited us on the top of the driver, who had been kneeling on the seat behind us; but the horse kindly waited till we had readjusted ourselves. The horses are small, and start with such a flourish from the yard that it is not always easy to avoid the gatepost; but, unfortunately, these exuberant spirits soon subside, and it is only with difficulty that the animal is persuaded to go at all.

Each inn, though small, has a guest room, which is certainly most scrupulously clean; the floor is painted white and so polished that you hesitate to walk on it with dirty boots. The houses are all of wood, raised off the ground a foot or two on granite boulders. Most of them are painted red, with white window frames and doorposts. Food is of the roughest—generally very hard rye bread, with excellent butter and plenty of milk. Sometimes there is a large wooden bowl in which milk has been let stand for a few days, from the top of which you scrape off the cream with a wooden spoon. Occasionally, too, you may get some very salt fish or a piece of smoke-dried reindeer.

Much of the rye bread is made in large flat circular cakes, of any thickness up to about a third of an inch, with a hole in the middle. Then they are strung on a stick passing through this hole, and hung from the ceiling for use when wanted. They have to be broken over the knee or with a hammer, and are not very satisfying when you are hungry.

We travelled three stages the first day, and then stayed for two nights at a small place called Pippola, on the river Kemi. Unfortunately our Finnish vocabulary was too limited to allow of any conversation but a request for food. However, we much enjoyed our short stay there, and were evidently a source of amusement to the natives, who were continually passing through our room during the night for the purpose of looking at us. A little way below the inn there were some rapids, and here the Finns had built an elaborate system of weirs for the purpose of catching salmon. We watched them scooping the fish with a net at the end of a long pole out of the pools where they were waiting for an opportunity of going up stream. I myself saw one Finn catch nine salmon in the net at one scoop. We were fishing for grayling, which much amused the Finns, who laughed at our small fish, and with great glee drew out two salmon at least for every grayling we caught.

It was while sitting on a rock amongst these rapids that we first watched Ospreys catch fish only a short distance from us. Two of these splendid birds were fishing there, sailing round and round high above our heads, and then hovering with their legs stretched out straight below them, scanning carefully the broken water of the rapids, which was glistening in the sunlight. Suddenly with marvellous sight one of them sees a grayling, and down he comes with a splash into the water; there is a sharp struggle, and then he flies away holding the fish below him in his talons, lengthways, with its head in the direction of flight. They carried the fish they caught far away over the forest, as though they were feeding young.

Again we went three more stages northwards, by the side of the river to Takkunen, a small inn like that at Pippola. The country now became much more hilly, and was quite covered with thick forest of birch and pine, and a few poplar trees. By the side of the river part was cleared for growing hay and corn. Next day three more stages brought us to Rovaniemi, a small town just on the Arctic circle, where the river Kemi flowing from the north-east is joined by the Ouras from the north-west. It is a pretty spot, surrounded by hills of a few hundred feet, from the tops of which you look over miles of undulating forest, and see two glistening rivers meet below you. Some of the hill-tops are of quite bare rock, showing clear signs of having been scraped by ice, and it is from these places that you can see the most glorious sunsets. The colours on the trees of the forest and on the wide sheets of calm water are beyond description.

The people are very short, with pale hair and eyes, and they all wear tall boots with curiously turned-up toes. They are fond, too, of a red or blue shirt. The Lapps, who were most of them away on the fells at that time of the year, are much darker, and are easily recognised by their curious dress, of which you have no doubt seen pictures.

The morning after we had arrived at Rovaniemi a large number of men came down the river from the north, clearing it of the timber logs which had caught on the shallows, and sending them on their way to the coast. They had quite a fleet of boats in which they dashed about the rapids, and the river for that day was crowded with them. They attacked one pile of timber after another, singing a curious chant as they heaved at the logs. It was wonderful to see how expert they were at moving about on floating logs, and jumping from one to another—not an easy feat, and I soon found myself in the water when I tried to walk out to them. In the evening they were to be seen at the small shops in the town, buying various garments, which one after another tried on in the street. Next day they were all gone with the logs, and the river flowed on unimpeded.

We stayed a week at Rovaniemi, and a most delightful week it was. We only had to go a few yards and sit down by the river's side to see numbers of ducks and divers floating almost like a procession down stream. As soon as they reached the end of the rapid water they seemed to fly up stream and float down again. Occasionally one would rest on a rock quite close to us and preen its feathers. Pintails, Mergansers, Golden-eye and Black-throated divers were there in abundance. What a difference there is in the way of diving between a true diver and a diving duck! The duck jumps out of the water and as it were takes a header into it so that you see its feet, but the diver seems to sink so gently that there is scarcely a break in the water.

Most conspicuous everywhere were families of Wagtails, bright spots of yellow and grey, running as only Wagtails can run, on the roads, the roofs of the houses, and the floating timber logs. Many of them were White Wagtails, but there were numbers of Yellow Wagtails too, not quite the same as our Yellow Wagtail which you can see in the meadows here during the summer, but two near relations, called Blue-headed, and Grey-headed; it was not unusual to have all three species round us at the same time.

In the forest we made the acquaintance of a new titmouse with a brown head, called the Lapp Tit, which was often to be found in the company of a large variety of our Marsh Tit; and I shall not easily forget our excitement one day as we were drifting down the river in a boat, when we were startled by a curious bleating noise and saw two Great Black Woodpeckers on the pine trees on the bank. They are large birds, always making weird noises, and we often saw them again—a country so full of dead trees and insects must be a paradise for them.

It was generally possible, too, to see some rough-legged Buzzard, circling high in the air, and to hear his kitten-like cry. One soon learns to distinguish between a Buzzard and an Osprey, even at a distance, for the Buzzard's wings seem quite straight and at right angles to his body, but the Osprey's wings are bent, and if you watch him long enough you will very likely see him hover. Many other birds there were, but stuffed specimens can give you little idea of what they are like when alive.

After a week at Rovaniemi we managed to get our luggage sent back to Torneå, and started to walk across the forest westwards, aiming at Alkula, a small town on the river Torneå. We were told that there was no track, but that if we walked 15 miles northwards by the side of the river Ounas we could then go most of the way by water through a chain of large lakes which stretches almost from one river to the other. We wished to walk, for little can be seen from a boat in the middle of a large lake, so we decided to go a little further northwards and then to try and find our way along the higher ground to the south of the lakes. Soon after we had started a fine Golden Eagle came close over our heads, pursued by two Rough-legged Buzzards. How small the Buzzards looked by the side of such a splendid bird! He sailed slowly round and round, rising higher and higher till all three were out of sight, The Buzzards kept making dashes at him, but they never seemed to touch him, and the only attention he paid to them was to utter a harsh croak occasionally. About midday we left the road and started through the forest with a compass as our guide. It was not long before we found that such travelling was not so easy as we had thought. We soon came to swampy and boggy ground, which was difficult to cross, and even on firm ground it was sometimes troublesome to fight one's way through thick forest.

I never really understood before what a forest is like, and I wish I could give you some idea of these northern forests. The trees are nearly all pines and birch, covered with long and hairy lichens, and grow in some places very close together, and at the same time there are numbers of dead trees lying on the ground, or half supported by living ones, so that you are always climbing over obstacles that lie in your way. Sometimes you tread on what seems to be a sound birch trunk, but it crumbles under your foot, for the wood has decayed though the bark is left. The ground is covered with mosses, and bushes bright with various kinds of berries, and every now and then you come to huge ant-hills, much larger than any you will see in

England, though I believe the species of ant is the same as ours.

On the hill tops there are few trees, for ice of ages past has scraped the ground so bare that vegetation can only grow in the crevices between the rocks. As you go down the hill the trees become thicker again and you may have to cross the wide track of some old morraine, where there are boulders piled one on another: if you are not careful, your foot will slip into deep holes between the boulders hidden by moss and rotten tree trunks. Still further down, the trees become thinner but the moss much deeper, reaching up to the knees. Presently the trees seem to end, and you come to a wide tract of flat ground where stand a few gaunt birches, long dead, and ready to fall at a touch. Here and there are tumps of dwarf birch bushes and coarse grass. This is a swamp, and as you go across it to the forest which you see again on the other side, the ground moves in waves around you, and between the small tumps on which you stand is horrid dark red ooze, into which you slip occasionally as you try to jump from one tump to another. The ground gets wetter and wetter, and at last you may have to wade through water up to your knees. It is useless to clutch at a tree for support, as you try some quaking bit of ground, for the tree is dead and falls upon you. If you stop for a few moments, you are at once attacked by mosquitoes, so that the only thing to do is to go steadily forwards and hope that you will not come to an impassable place or be swallowed up by the bog.

The coarse grass which grows about these swamps is sometimes cut by the natives and stored in rough little log huts until it can be fetched on sleighs in the winter to their homes. The farms are always by the side of a river or lake, so that the people can communicate with each other by water, and most of the paths in the forest seem to lead to the swamps, to which they go for grass.

We had only left the road a short time when we got into swamps such as I have described; but towards the evening, after finding our way round a lake and across a stream, we were lucky enough to come upon a small farm and slept comfortably in one of the hay huts. Next morning we were ferried across a stream by the farmer, and found a path which brought us to another settlement by the side of a large lake. But soon after midday our path took us into the middle of a huge swamp and then deserted us, so we kept our direction again by the compass and presently got on to some higher ground, where we saw our first reindeer. Fortunately, he was quite as interested in us as we were in him, and so we sat down quietly while he kept trotting round us with a curious shambling trot, snorting with astonishment or indignation. His hoofs are very large and make wide tracks on the ground, which must be of great assistance to him when travelling over snow in winter. Presently we saw another, and on the top of the hill found an open sandy bit of ground, which was evidently much frequented by them to judge from their tracks.

All the rest of that day we walked through forest of all sorts without seeing any sign of mankind, but towards evening we arrived at a small lake surrounded by swamp and found there some very rough hay huts, into one of which we crawled for the night.

What a night it was! In the middle of a lonely forest swamp, probably some miles from any human dwelling and not twenty yards from the water of the lake, on which were numbers of duck and geese. The wild geese were continually flying close to us and splashing about on the water, making strange noises all night. We were thankful to lie in the hay and try to dry our feet, but there was not much sleep to be got, for myriads of mosquitoes and midges assailed us on all sides. Behind us we could hear owls screaming in the forest.

Three reindeer were close to us next morning when we started cheerfully in the hope of finding the hay-cutter's path to his house; but the path only led to the side of a large lake, across which he used to row in his boat, and presently we were toiling through larger swamps than ever. But Siberian Jays, another new bird, did much to encourage us: they are most handsome creatures with dark heads and much rufous colour on the tail and flanks, and were so tame that one picked up a worm within a few yards of us. We were, however, thoroughly tired of swamp and moss that morning before we got out of it, and hungry too, and were glad at last, from the top of a hill, to see a wide lake below us, with a farm by the side of it.

What a splendid bathe we had in the lake, and how we enjoyed the bread and the large bowl of cream in a corner of the rough room of the farm, while our entertainers sat on a bench, and occupied themselves with hunting for insects in a way that reminded us of the monkeys in the Zoo! On the land side this farm seemed to be surrounded by swamp, and so with difficulty we at last persuaded two women who were reaping their corn to take us somewhere in a boat. They sat in the stern, and steered with a paddle, while we rowed with most peculiar sculls, sitting on the bottom of a very leaky boat, until we reached a rather larger settlement, about five miles off, on the other side of the lake. Here we spent the night in a house in which four generations were living together. The great-grandmother looked by far the oldest woman I have ever seen. She was quite blind, and very scantily clad, and wandered about barefooted, with a long stick, crying out piteously every now and then, when she did not know where she was.

From this house we travelled the greater part of the next day on two large lakes (Raanajarvi and Miekojarvi), rowing ourselves, while women or an old man steered with a paddle. Then for two more days we walked through the forest, sometimes being forced to retrace our steps by a swamp we were unable to cross. Once a Finn guided us for some way, and then, before leaving us, explained, by drawing a diagram on the ground, how we should come presently to a lake, round which we should have to make our way, to find a path again on the other side. The paths are often faint and difficult to follow, so that you have to be careful to watch for marks cut on the trees. In the evening of the same day another very good-natured Finn took us quite a long way through most intricate forest, passing with such ease and swiftness under the low branches of the trees that we had difficulty in keeping pace with him. He left us on a path which took us to a night's lodging, and would not accept more than $2\frac{1}{2}$*d.* as a token of our gratitude, which "Kiitoxia, kiitoxia"—the only word of thanks we knew—could not adequately express.

All the natives were wonderfully good-natured, and were always ready to do what they could; but it was not so easy to make them understand what we wanted, and they generally took a little time to recover from astonishment at our appearance. One old man, whom we met in a swamp, slashing at the grass, first on one side and then on the other, with his curious, short-handled scythe, was most provoking. We were a little annoyed at not being able to cross the swamp and the stream which flowed through it; and I can see him now, laughing at us and saying, "Eeumoron, Eeumoron," to all our gesticulation, until we left him in disgust. "Eeumoron" we found to be a common exclamation of the country.

There is one more bird I must mention which no one could see without delight. As we were starting on the last morning of our forest walk, we heard a curious chattering sound in the pine trees near, and soon found ourselves in the midst of a flock of Waxwings, chattering to one another, with crests erect, as they sat on the ends of the boughs in the sun. They were very tame, and I wish you could have seen them—so different in their life from the stuffed specimen in a museum. While we watched them, one darted off his perch in chase of a dragon-fly.

On this last day, too, we were ferried across a river by thirteen logmen, like those we saw at Rovaniemi. They sang a most curious dirge as they rowed, which still rings in my ears, though I cannot reproduce it. We had a long walk that day, and reached Alkula at length, passing by the mountain Aavasaxa, from the top of which you can see the midnight sun, although not within the Arctic circle. We were rather disappointed with Alkula, for we could not get the meal to which we had been looking forward during the last day or two, and so went on southwards along the remaining 42 miles of road to Torneå without delay.

At Haparanda we were in luxury again, and soon continued our journey southwards by steamer to Stockholm. But we were not to be without birds, for they were our fellow-passengers in the Gulf of Bothnia, and again in the North Sea, when we crossed from Christiania to London. Members of no less than nine species took short rests on our steamer as they were making their long journey to their winter quarters. It was pleasant to see the confidence with which they ran about the deck, and perched close to passengers, at times trying short flights, and then coming back again to rest until they felt strong enough to continue their journey. And as one watched them fly away out of sight, close to the waves, that mysterious impulse which causes the birds to go such enormous distances seemed to make one struggle to go with them.

The Chemistry of Colliery Explosions due to Gas derived from Coal-dust.

By DONALD M. D. STUART, C.E., F.G.S.

(*Read Jan.* 26, 1897.)

THIS subject has received constant attention by physicists, chemists and engineers, from the early years of this century. The explosions were generally supposed to be due to the ignition of a gaseous mixture, termed firedamp, of which the following anaylsis by Lord Playfair represents an average composition :—

	Hebburn Lit.
Methane	91·8
Carbon dioxide	·7
Oxygen	·9
Nitrogen	6·7
	100·0

The presence of the firedamp in the atmosphere of the mine was disclosed by its combustion over the flame of the candle or safety lamp. When the firedamp was diffused in a volume of the atmosphere, so as to form an inflammable or an explosive mixture, and exposed to an unprotected flame, varied effects ensued from a simple burning without disruptive energy, to the mutilation of men and destruction of the mine. These effects were limited to the immediate vicinity of the explosive mixture; but the phenomena of explosion were found for thousands of yards beyond, where firedamp could not be conceivably present. The ignition of the firedamp may have been the initial cause of the explosion, but the extensive phenomena beyond, demanded for their explanation an explosive agent of coextensive distribution. Investigation has shown that coal-dust was universally present, and the only agent capable of giving rise to explosion.

Faraday and Lyell examined the Haswell Colliery after the explosion there in September, 1844, and in their report to the government they said *: "In considering the extent of the fire from the moment of the explosion, it is not to be supposed that firedamp was its only fuel: the coal-dust, swept by the rush of wind and flame, would instantly take fire and burn, if there were oxygen enough present in the air to support its combustion; and we found the dust adhering to the faces of the pillars, props, and walls. This deposit adhered together in a friable coked state. When examined with the glass it presented the fused round form of burnt coal-dust; and when examined chemically, and compared with the coal itself reduced to powder, was found deprived of the greater part of its bitumen, and in some instances entirely destitute of it. There is every reason to believe that much coal gas was made from this dust in the very air itself of the mine, by the flame of the firedamp which raised and swept it along, and much of the carbon of this dust remained unburnt, only from want of air."

"In January, 1845, Faraday delivered a discourse at the Royal Institution, in which he dealt with this Report, and

* Final Report of Royal Commission upon Accidents in Mines. pp. 30, 31.

the experimental inquiry made by himself in reference thereto. The substance of his conclusions, regarding the part taken by coal-dust in the Haswell disaster, was then given in these words: 'The ignition and explosion of the firedamp mixture would raise and then kindle the coal-dust, which is always pervading the passages, and these effects must in a moment have made the part of the mine which was the scene of the calamity, glow like a furnace.'"

Faraday's view of the function of coal-dust in the Haswell explosion was, that it was thrown into suspension and ignited by the explosion of firedamp, and then burned like coal-dust burns in a furnace.

Twenty years later, "1864–67, M. Verpilleux made experiments which led him to the conclusion that coal-dust played an important part in coal-mine explosions." *

In 1875 M. Vital made special experiments with coal-dust, and "Concluded that very fine coal-dust, rich in inflammable constituents, will take fire when raised by an explosion, and that portions are successively decomposed, yielding explosive mixtures with the air, whereby the fire is carried along, the intensity or violence of the burning being much influenced by the physical character of the dust. He also suggested that an explosion of firedamp, although taking place instantaneously, may inflame or decompose a small quantity of coal-dust raised thereby, explosive action being thus propagated after the firedamp explosion has ceased." †

In 1878, Marreco confirmed the conclusions of Faraday and Vital. He observed "that the coal-dust is in part submitted to destructive distillation during the progress of the flame through the dust-laden air." ‡

* Final Report of Royal Commission upon Accidents in Mines, p. 31.
† *Ibid.*, Report, p. 31. ‡ *Ibid.*, Report, p. 32.

In 1882 Mallard and Le Chatelier, members of the French Firedamp Commission, carried out extensive investigations and experiments. They found that gaseous matters were evolved from the coal-dust by the action of the firedamp explosion, but arrived at the conclusion that no explosion of importance could be attributed to the action of coal-dust alone.*

In Germany, the Firedamp Commission (Saarbrücken), 1884, found that a charge of blasting powder when fired into an atmosphere laden with coal-dust ignited the dust, and flame was propagated through the mixture to a limited extent; but that certain descriptions of coal would, in the same circumstances, give rise to explosive phenomena, resembling the phenomena arising in the ignition of a mixture of 7 per cent. of firedamp with air.†

In addition to Marreco's investigations in this country, Messrs. Galloway, Hall, Cochrane, Sir Frederick Abel, and others, carried out experiments, commencing in 1875, confirming the conclusions of Faraday, Vital, and Marreco, and concluded that coal-dust itself, in the absence of firedamp, would cause an explosion, which required for its origination only the flame of an ignited local body of firedamp and air, or a charge of blasting material. All the investigators, from Faraday, in 1845, up to Professor Harold Dixon, in 1893, concluded that the function of coal-dust in an explosion was that of a solid in a fine state of division, in admixture with air, undergoing distillation at a temperature at which the educts could enter into combination with the atmospheric oxygen. This theory did not appear to take

* Final Report of Royal Commission upon Accidents in Mines, pp. 45, 46.

† Second Report of Royal Commission upon Explosions from Coal-dust, p. 6.

adequate cognizance of the fact that the energy of coal-dust in combustion does not, like that of a blasting material or an explosive substance, reside in the inflammable body alone, but in a system composed of coal-dust and the air necessary to burn it. Coal-dust can only be an explosive agent by virtue of the combustible gases it yields by dry distillation. When the distillation is conducted with the coal-dust in atmospheric suspension, at a temperature at which the educts can enter into combination with the atmospheric oxygen, the gases are burned immediately upon their liberation, producing flame, but no disruptive energy.

The explosions in mines caused great destruction; men were found literally blown to pieces, and tunnels wrecked, exhibiting the effects of forces of disruptive energy, which were unaccounted for in the theory of combustion referred to.

The explosions were found to have been propagated from the point of origin to remote places in the mines, and Messrs. Hall and the Atkinsons, H.M. Inspectors of Mines, advanced an hypothesis of a travelling blast, while Professor Dixon adopted the term of "a flame," rushing along each path of propagation. Numerous disruptions were, however, found in these paths, and, at their loci, the broken and displaced materials were observed lying in opposite directions; *e.g.*, at Timsbury collieries a wagon was found broken up,—one end was discovered inwards, the other outwards.* At the Albion Colliery a train of wagons standing in a siding was divided about the centre, and the two parts were discovered some distance from each other, one portion in the eastern entrance, the other in the western entrance of the siding.† This phenomenon was frequently

* The Origin and Rationale of Colliery Explosions, p. 15.

† *Ibid.*, p. 76.

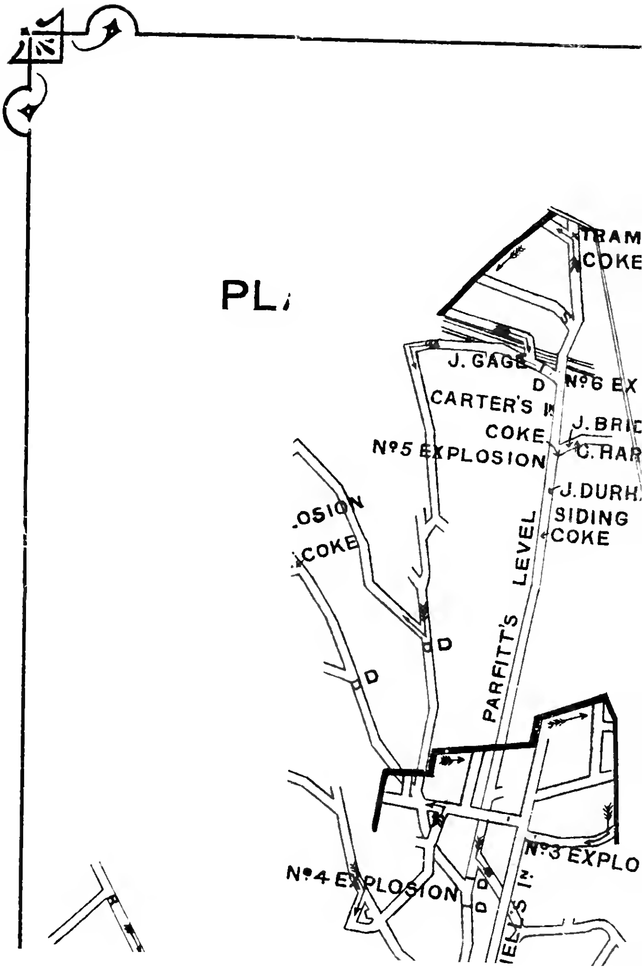
observed, and the supporters of the hypothesis of a continuous blast designate it as "conflicting evidence of the direction of force," and caused by a "return blast." Professor Dixon's explanation is that the phenomenon is "due to a wave of air propagated backwards when the explosion has again gathered strength, or to one of those oscillations of flame which are seen in laboratory experiments." *

This shattering and displacement of wagons exhibited the effects of ignition of highly explosive mixtures; consequently no second mixture of this nature could have remained at these places, nor in juxtaposition, for a second or return blast. It is difficult to understand how a wave of air propagated backwards, or an oscillation of flame, could displace and carry away ponderous bodies, including masses of iron. If a wave of air, or the flame, were capable of moving the train of wagons referred to, it must have carried the train in one direction; therefore the primary wave would leave all the wagons in the eastern entrance of the siding. The "wave of air backwards" must then have passed over the first half of the train without mechanical effect, but on reaching the centre, suddenly developed propulsive energy to hurl the remaining half away to the western entrance, leaving the antecedent part at rest, which is also difficult to understand.

The hypothesis of the combustion of a mixture of coal-dust and air, continuous or instantaneous, through the field of disaster, was opposed by the phenomena of the disruptions; and no attempt was made to elucidate the chemical and physical activities in the propagations through thousands of yards of tunnels beyond the point of origin.

The small quantity of heat disengaged in the explosion of charges of less than one pound of blasting powder, or of a

* Report, Albion Colliery Explosion, p. 2.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THE TIMSBURY COLLIERIES.

PLATE I.

PLAN OF WORKINGS TRAVERSED BY THE EXPLOSION.

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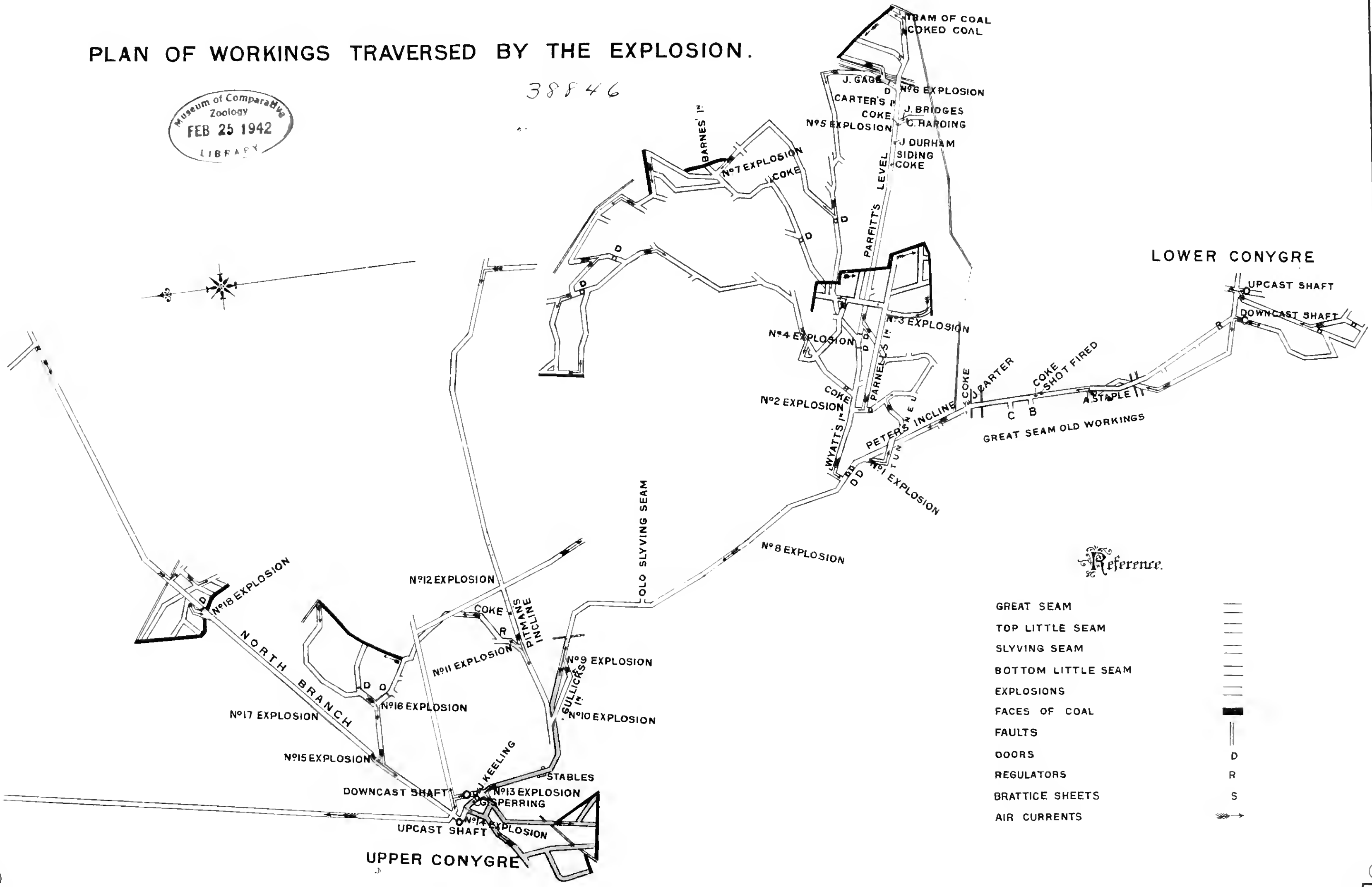


local body of methane and air, was utterly inadequate to account for the explosive phenomena found through such distances; and the source of the immense quantities of heat necessary for the propagation of the explosion beyond the boundaries of the original explosive mixture, or the vicinity of the blasting charge, had not been investigated. Notwithstanding what has been placed before the scientific world concerning the part taken by coal-dust in colliery explosions, with the ignition of small accumulations of methane and air, or the explosion of small charges of blasting substances as the sole source of heat, an explanation of the phenomena of the explosions was still wanting.

Up to this date, 1893, all the colliery explosions in the United Kingdom had occurred in mines known to contain fire-damp; but an explosion now happened at the Camerton Collieries, Somersetshire, followed by another at the adjoining Timsbury Collieries. Methane had not been found in these collieries during their history of seventy to one hundred years. Coal-dust was the only material in the mines capable of giving rise to explosion and coextensive with the field of explosive phenomena. The explosions therefore offered opportunities for observing the deportment of coal-dust in the absence of methane, upon the scale of a colliery explosion, and in the ordinary conditions of coal-mining. The observations and measurements of the effects in the mines occupied me eight days; and as they provide the evidence from which the energies which produced them are to be elucidated, it will now assist the discussion if we consider the observations.

The plan of Timsbury Collieries exhibits the field of an explosion. The shot that originated this disaster is indicated, with the successive loci of disruption, which it will be observed were at intervals in the tunnels.

The disruptions exhibited the effects of destructive energy in local areas at intervals, varying from 38 yards to 343 yards.* Loaded and empty wagons, previously left standing upon the rails, were found lying in all directions, their contents scattered abroad, the woodwork, iron attachments, wheels or axles bent or broken; strong doors fixed to guide the ventilating currents had been shattered to particles and scattered along the floor of the tunnels for fifty yards beyond the remains of the door-posts, while the strap iron hinges, weighing 14 lbs. each, were lying 20 to 30 yards away, bent into semicircles, or broken through the bolt holes; the rails were torn from the sleepers; wood structures, built of beams 10 and 12 inches square, were broken up; brick and stone arches were dismantled; beds of stone forming the roof, and supported by occasional props, were broken down in thicknesses of 1 to 4 feet, in lengths from 4 to 25 yards; frames of timber, thickly fixed under weak or faulty roof, were thrown down and falls of strata caused, measuring from 400 to 800 tons. One of the victims was shockingly mutilated, and others in the vicinity of a disruption had their clothes partly torn from their bodies.

The spaces between the disruptions presented the following contrasts: the victims were not mutilated, not a bone was broken, nor their clothes disturbed; quiet death by suffocation was all that could be observed; the thickly erected frames of timber sustaining weak and faulty roof were in their normal positions, and the strata undisturbed; brick and stone arches were undamaged; wood structures were also undisturbed; rails and sleepers were unmoved; and loaded and empty wagons were standing upon the

* Coal-dust an Explosive Agent, p. 30.

rails as they had been left, the wagons uninjured, and their contents again undisturbed.

These observations show that the tunnels, with the timber supports and arches, and the materials they contained, at the loci of the disruptions and in the intervals between, were of equal strength; consequently the resistances they offered to destruction were identical, and the contrasts in their condition exhibited, in juxtaposition, the effects of disruptive energy and their absence. The phenomena in the disruptions and the phenomena in intervals therefore exhibit distinct modes of energy.

The materials displaced in the disruptions were found lying in opposite directions, or in radial lines, and exhibited the effects due to local explosions. The destruction recorded could only be caused by forces moving at the immense velocity known in the ignition of explosive mixtures; and this is obvious when it is remembered that the disruptive energy was exerted through the instrumentality of a mass of air which, by impact, wrought the shattering effects observed, and must therefore have moved at the immense velocity referred to.

The condition of the tunnels in the intervals from disruption to disruption, shows that the disruptive energies were expended at the loci of the explosions, and that there was a comparatively slow gaseous movement between them, which allowed time for the distillation of the coal and the formation of the explosive gaseous mixtures, to the ignition of which the successive local explosions were due.

The field of disaster at Camerton Collieries presented the effects of ten local explosions at intervals in the paths of coal-dust, approaching one mile in length.*

* Coal-dust an Explosive Agent, pp. 29, 30.

There are other phenomena that throw light upon the velocity of the gaseous movement in the interval from explosion to explosion. It has been already mentioned that in places there was inadequate velocity to move the wagons along the rails, disturb the pipes, carry away the food bag, or the men's clothes. About 300 yards from the shot or point of origin, and in the interval between No. 5 and No. 6 explosions, there were some wagons of coal standing upon the rails in a siding in the path of the coal-dust. The wagons had one open end in which the lumps of coal were built as a wall. The coal in the end of the hindmost wagon was exposed to the gaseous movement initiated by No. 5 explosion, and about 60 lbs. in lumps from 4 oz. to about 4 lbs., were missing, and no trace of it could be found in the siding. Two timber beams, each 6 feet long, lying against the roof, over this and the adjoining wagon, were coated with a friable deposit of coked coal throughout their length and upon their opposing faces; and amorphous carbon was in profuse distribution upon the vertical timber and side walls. At the Timsbury Collieries a wagon of coal was resting on the rails about 70 yards beyond the sixth explosion, with blocks of coal raised above the wood-work. The faces of this coal had burst out into globules of bituminous matter, which had undergone further destructive distillation, leaving residues of comminuted coke. Globules still remained attached to the faces of the coal in different stages of formation; and the ledges of the coal, the edges of the wood sides and ends of the wagon, and the buffers, were loaded with accumulations of coke the size of small shot, which had gravitated downwards from one resting-place to another. The reduction of blocks of coal by heat, in the conditions prevailing in a colliery explosion was exhibited at this wagon, and confirmed the supposition that the coal in the wagon at Camerton Colliery had been removed by an analogous agency. The globules of coke at Camerton Colliery ascended almost vertically to the overhanging timber, and remained deposited there, but at the wagon at Timsbury Colliery the globules gravitated to the floor. In both cases the gaseous movement following the antecedent explosions was of inadequate velocity to carry the particles of coke beyond the wagons; consequently the movement in the interval from explosion to explosion was at a velocity that admitted the element of time for distillation and the formation of the gaseous mixtures for the successive explosions.

The source of the combustible gas is indicated by the residues of coked coal observed in the fields of the disasters, which show that the coal-dust had undergone dry distillation, and gaseous hydrocarbons had flowed into the atmosphere of the mines. The subsequent history of these hydrocarbons must provide evidence for elucidating the chemical and physical actions that produced the explosions.

Observations in the tunnels disclosed the presence of a black impalpable powder upon the side walls and side timber throughout the fields of explosion. In many places it was in gossamer-like form, giving the vertical faces of timber and stone a veined appearance. These filaments were collected upon paper, but broke down into powder under the slightest pressure. The general deposit was upon the vertical faces of the side walls in a loosely built-up sponge-like stratum, which shrunk to a fraction of its original thickness when touched with a flat surface. This deposit was amorphous carbon. The exploring parties that entered the mines immediately after the explosions found the atmosphere laden with this carbon, and compared it to the condition that would arise by shaking a feather-bed tick in the air.

This condition of the atmosphere afforded an explanation of the sponge-like form of the depositions of carbon on the side walls, which were evidently accumulations formed by successive settlements of particles previously in atmospheric suspension, and the deposition of striated filaments could arise in no other way.

The carbon having been originally in atmospheric suspension, its origin in that atmosphere must now be sought. The explosions broke down the ventilating doors, filled the tunnels with occasional falls, and stopped the circulation of the air currents; the products of the chemical actions in the explosions and in the intervals, were imprisoned between the falls. The spaces between the disruptions were therefore filled with still atmospheres, that could only be displaced by diffusion. The exploring parties frequently advanced into these atmospheres to make apertures through the falls, that, in addition to displacement by diffusion, the motive column of the ventilation could be made effective to force the stagnant gases along the tunnels to the upcast shaft. The explorers were constantly standing in the still atmospheres, in which their candles burned brightly, and it was only after exposure for some time that they felt sensations of faintness, stupefaction, and unconsciousness, necessitating retreat into pure air, until diffusion was exerted to enable them to advance again.

During the occurrence of the explosions in Camerton Collieries four men were working in the North Branch. They received their air by a current through Probert's dipple, which the explosion there, had suspended. They felt a change due to the suspension of their supply of air, and immediately retreated through the products of Nos. 8, 9, and 10 explosions. Their lights burned brightly, and they suffered no faintness during their exposure of over an hour. This fact is of interest since Dr. Angus Smith found, by experiment many years ago, that the flame of a candle was extinguished in an atmosphere containing 2 per cent. of carbon dioxide, and over forty years ago Le Blanc observed that an atmosphere containing 0·54 per cent. of CO caused faintness and death, and that it was due to prolonged exposure to the very small percentages of this gas in the gaseous products of colliery explosions, that from 80 to 85 per cent. of the deaths were due, and these facts have been constantly verified. The burning candles of the survivors at Camerton Collieries indicate the absence of more than 2 per cent. of CO_2; and their escape, the absence of 0·54 per cent. of CO in the still atmospheres.

These small quantities of the oxides of carbon show that the carbon constituent of the hydrocarbons was not appreciably oxidised, and the presence of the carbon in copious suspension in the gaseous products, with its profuse and general deposition upon the side walls throughout the fields of explosion, is the evidence of fact that it was almost wholly separated from the hydrogen, and not oxidised. The amorphous carbon, therefore, had its origin in the educts of the coal, and was removed from the sphere of action, leaving hydrogen for effecting the phenomena of the explosions.

Attention may now be turned to the phenomena at the origin of the explosion, as, if the chemical changes from the point of origin to the first hydrogen explosion be elucidated, the propagation along the paths of coal-dust will present no difficulty.

The heat of the exploded powder was first employed in breaking and displacing a small portion of rock, and in heating and cracking rock that was not displaced; the products, however, retained an unexpended quantity, which was projected through the planes of rupture into the coal-dust at a high velocity, initiating distillatory action, which left residues of coked coal upon the floor, timber, and other surfaces over an area of 30 square yards in the immediate vicinity. The first disruptions were at 136 and 140 yards respectively from the shot, and the only heat available to sustain the distillatory action in the coal-dust through these distances, and supply other demands, was the surplus that remained from the fired blasting powder.

The charge of powder contained 12½ ounces, or 354·37 grammes, and, taking the calorific value as determined by Abel and Nobel at 516·8 small calorics per gramme, the total heat disengaged would be $354{\cdot}375 \times 516{\cdot}8 = 183141$ gramme units. The quantity of heat transformed into work, causing mechanical effects upon the rock, can only be estimated; but experience in the use of explosives enables this quantity to be fixed with approximate accuracy, and in the case under notice, less than one quarter of the charge would cause the effects observed, leaving practically 140,000 gramme units for other purposes.

The products of explosion of mining powder of average composition are, by weight:—

Gaseous	51·35
Solid	47·04
Water	1·64
	100·00

The temperature of explosion of mining powder was determined by Abel and Nobel at 2896° C upon the specific heat of the products of combustion; but their experimental determination was 1800° to 2000° C in the conditions of the experiment.

When the blasting charge was fired, products of combustion holding 140,000 gramme units of heat were projected through the planes of rupture in fan-like sheets into the coal-dust. The products would suffer diminution of temperature in expansion through the planes of rupture and through the air; but the velocity of projection through the distances of 4 to 8 feet between the shot and the coal-dust would not permit any important surrender of heat to the faces of rock or the air, and the products would be at an exalted temperature when they struck the coal.

The temperature of distillation of coal in the gas retort is under 1000° C, and the educts are (*London Gas*, *Frankland*):—

H	51·24
CH_4	35·28
CO	7·40
Olefines	3·56
N	2·24
CO_2	·28
	100·00

The first educts from the coal-dust would be represented by this composition with the addition of some impurities, and the point to note is that hydrogen not in combination with carbon, forms over 50 per cent., and gaseous hydrocarbons over 38 per cent., of the gases.

These educts would be ignited and burn immediately upon their liberation from the coal if adequate oxygen were present, and distillation and combustion would continue along the path of coal-dust so long as oxygen was available, and sufficient heat was disengaged to sustain the actions; but, as already observed, such combustion has no disruptive energy, and the oxides of carbon would enter largely into the composition of the products.

The preceding observations show that immense disruptive energy was exerted in the path of the coal-dust, and the oxides of carbon were not present to the extent of the small percentages appreciable by ordinary tests, because the carbon constituent of the hydrocarbons was not appreciably oxidised; therefore the nascent educts of the coal-dust did not undergo general combustion.

I have elsewhere * suggested that the educts of the coal were in excess of the relative combination volumes of atmospheric oxygen present; that the nascent free hydrogen in the educts seized the principal part of the oxygen, and was oxidised, liberating heat. A small quantity of oxygen would be taken by some of the hydrocarbons, producing combustion analogous to that known in the preparation of lamp-black and diamond-black, disengaging more heat, and leaving carbon in suspension in the products.

Above the temperature of 1000° C some of the hydrocarbons undergo dissociation, and at the temperature of burning hydrogen, methane, the most stable hydrocarbon, would be dissociated, since it decomposes at 1500° C; more carbon would thereby be thrown into suspension, and free hydrogen placed at disposal for disruptive action.

The heat in the products of the exploded powder is therefore suggested to have initiated a series of chemical actions in the coal-dust, in which large quantities of heat were disengaged, free hydrogen placed at disposal, and carbon left in suspension.

This series of actions was regenerative by virtue of the heat disengaged, and instituted a similar series in the adjacent coal-dust; and these activities were of constant

* The Origin and Rationale of Colliery Explosions.

and similar reproduction along the path of coal-dust, hydrocarbons being dissociated and free hydrogen accumulated, until a place was reached where large supplies of oxygen were available; and there being an ignition temperature at command as the result of the oxidation referred to, the accumulated hydrogen was oxidised with disruptive energy, causing the destruction observed at the first disruption.

This explosion of hydrogen liberated a much larger quantity of heat than that available from the exploded mining powder; therefore an advancing series of similar changes to those described were again established in the coal-dust beyond, causing a second explosion farther away, where the conditions for the oxidation of the second accumulation of hydrogen were complete; and succeeding explosions would be caused along every path of coal-dust where adequate atmospheric oxygen was available, and no wet surfaces intervened, to reduce the temperature below the point at which the dry distillation of coal yields sufficient free hydrogen to supply by its oxidation enough heat to make the actions continuous.

The explosions occurred at points in the paths of coal-dust where the tunnels of normal sectional area suddenly expanded into capacious places, as at junctions, or cavities in the roof, and where the air became concentrated. The loci of explosion were therefore coincident with the presence of abnormal supplies of the atmospheric oxygen.

There were inflammable materials in the paths of the explosions which had been exposed to heat, but not consumed. The hair of the horses was simply singed; the hair of the victims was also singed; their clothes were not burned, and their burns were blisters, the skin and flesh had peeled; the calico food bags were not consumed, and the coal-dust on the floor of the tunnels, and the lumps in the wagons had been subjected to dry distillation, not combustion. These effects upon coal, horses, men, and calico bags disclose the fact that the atmospheric oxygen in the tunnels of the mine was, at most, not more than adequate to supply the requirements of the hydrogen in the educts of the coal undergoing distillation; consequently there was no oxygen available for the chemical requirements of other combustible bodies, as the timber, coal, clothes and food bags, and they could only exhibit the effects of gaseous water upon them.

Another effect of the oxidation of the hydrogen is indicated at Timsbury collieries. In the path of the explosions, three tunnels branched off at right angles into extensive old workings, which had an indirect connection with the down-cast shaft. The entrances of these branches were filled up by dry stone walls in two cases; the third, being a large place, was closed up with a wall of masonry. These vertical walls were erected to prevent the air current leaking into the old workings, and in the ordinary operations of the mine they retained their positions, the atmospheric pressure being equal on both sides. After the explosion, all three walls were found thrown down into the path of the explosion, indicating that the pressure of the air in the old workings behind them was at the moment of their displacement greater than the pressure in the tunnels. In the combustion of the hydrogen in the educts of the coal, one-fifth of the volume of air in the tunnel would be taken to form twice the volume of water vapour, which would undergo instantaneous condensation, the enclosing walls of the tunnel being at a temperature of not more than 15° C. The volume of permanent gases in the tunnel would thereby be reduced by one-fifth, forming a partial vacuum of 3 lbs.

per square inch, or 432 lbs. per square foot, and the resistance of the side walls of the tunnel to external pressure would be diminished to that extent. The pressure of 432 lbs. per square foot represents a wind velocity of 300 miles per hour. The highest velocity observed by Rouse was 117 miles per hour, which overturned buildings; and this fact will remove any difficulty in understanding how the walls in the branch roads of the tunnel were overwhelmed when suddenly deprived upon one side of a pressure represented by a wind velocity more than twice as high as Rouse's greatest hurricane, while the pressure upon the other side was undiminished.

No. 18 explosion was the final outburst in that direction, and the door beyond was forced open by the air upon the opposite side, also showing reduced pressure in the field of the explosion. This phenomenon of doors lying open towards the seat of explosion is not uncommon in colliery explosions.

The partial vacuum that is seen to have a place in the field of explosion, and arising in the chemical changes in the educts of the coal, indicates that the products of these changes were not permanent gases, but a gas that was instantaneously condensible, and gaseous water was the only body of this nature that could be produced from the educts.

The remaining phenomena of the explosions also demand, for their explanation, the chemical changes that have been advanced.

The theory of the explosive wave enunciated by Berthelot is of great interest in connection with the foregoing phenomena. It will be remembered that he experimentally determined the velocity of the wave in the explosion of a mixture of two volumes of hydrogen and one volume of oxygen to be 2,810 metres, or 9,219 feet, per second, and Professor Dixon has recently arrived at almost identical figures.

The origin and propagation of the explosive wave was also investigated by Berthelot, who observes that the wave developed in an explosive mixture consists of chemical actions transformed into calorific and mechanical energies, and when once originated, propagates itself without diminution of force, because the chemical and physical actions that develop it regenerate its energy throughout the matter undergoing transformation. The explosive wave, he continues to say, propagates itself in the substance which explodes by virtue of a series of shocks incessantly reproduced, which regenerate its energy.

Propagation of the explosive wave in intermediate substances as air, whose nature is not changed, is purely physical, and is effected solely by virtue of the energy of the last shock, an energy which is no longer regenerated and which rapidly weakens by distance.

Propagation of the explosive wave ceased when the theoretical temperature of the compounds formed with free oxygen fell below 2000° C, for hydrogen associated with nitrogen; also when the products of combustion amounted to less than a quarter of the total volume of the final mixture, and no propagation was observed below 1,000 metres, or 3,281 feet per second.

Propagation only occurs when the inflamed molecules preserve almost in its entirety the heat developed by chemical action; consequently the maximum velocity and maximum translating energy.

These researches show that the explosive wave developed in the gaseous mixture in the mine possessed a velocity that explains the shattered effects observed in the disruption, as well as its local character, inasmuch as the wave was not propagated beyond the immediate vicinity of that mixture, because its energy was no longer regenerated, and the conditions of temperature and products necessary to propagation had ceased. The disruption is consequently followed by quiescent conditions, in which a second explosive gaseous mixture is formed, and a second local explosion occurs where it is ignited.

The experimental researches of Berthelot into the behaviour of explosive mixtures upon ignition are therefore in agreement with the phenomenon of local explosions at intervals along the paths of coal-dust.

These explosions along the paths of coal-dust were arrested in air that had already ventilated other parts of the mine, and was consequently poor in oxygen; also in small currents of air of limited resources and in receding currents, the oxygen of which was being constantly exhausted. In these conditions, there was inadequate oxygen to burn a sufficient quantity of hydrogen to maintain the temperature of the distillation, and the chemical changes stopped with the failure of the supply of heat. Where wet surfaces intervened in the path of coal-dust, the conditions of instantaneous condensation were perfect, the product of the hydrogen and oxygen surrendered its heat with the rapidity observed in a steam condenser, and distillation was again arrested by want of heat.

Propagation of the hydrogen explosions, therefore, failed in wet places, and where atmospheric oxygen was insufficient to sustain the chemical actions.

The principal phenomena of the explosions at the Camerton and Timsbury collieries have now been referred to, and the examination has led to suggestions of their causes, which enable the proposed rationale to be shortly stated as follows:—

A colliery explosion in which coal-dust is the principal agent is originated by the heat in the products of an exploded blasting agent, or ignited inflammable gas, instituting a series of chemical changes in the coal-dust, commencing with distillation, followed by chemical and physical changes in the educts which liberate heat, place free hydrogen at disposal, and re-establish the series in the adjacent coal. This series of actions is of constant sequence or reproduction along the path of coal-dust until a place is reached where the supply of atmospheric oxygen is increased and the accumulated hydrogen is exploded, causing disruptive effects, but leaving sufficient heat to repeat the phenomena beyond.

In conclusion, this theory accounts for the coked residues of coal and the positions in which they were found; explains the presence of amorphous carbon in suspension in the atmosphere, and its characteristic deposition upon the side walls throughout the fields of disaster; accounts for the comparative absence of the oxides of carbon in the gaseous products; supplies the heat for distillation, dissociation, and other demands; allows time for the distillation of coal and the chemical changes in the educts; provides explosive gas for disruptive purposes; explains the occurrence of disruptions at intervals, the intervening periods of rest from disruptive action, the conditions under which propagation proceeds or is arrested, and excludes no coal except that which yields no combustible gases when subjected to the temperature of dry distillation.

The Homologies of the Horn-Structures in the Ungulata.

By S. H. SWAYNE, M.R.C.S.

(*Read March 4th*, 1897.)

BEFORE entering on the particular views which I wish to bring forward, I think it well to quote as an introduction the commonly received account of these organs, which is ably set forth in the article "Horn" in the ninth edition of the *Encyclopædia Britannica.*

The article says: "The weapons which project from the heads of various species of animals constituting what are known as 'Horns' embrace substances which are in their anatomical structure and chemical composition quite distinct from each other, and although in commerce also they are known indiscriminately as 'horn,' their uses are altogether dissimilar. These differences in structure and properties are thus indicated by Professor Owen: 'The weapons to which the term horn is properly or technically applied consist of very different substances, and belong to two organic systems as distinct from each other as bones are from teeth. Thus the horns of deer consist of bones, and are processes of the frontal bone; those of the giraffe are independent bones, or "epiphyses," covered by hair; those of oxen, sheep, and antelopes are "apophyses" of the frontal bone, covered by the corium and by a sheath of true horny material; those of the prong-horned antelope consist at their bases of bony processes covered by hairy skin, and are covered by horny sheaths in the rest of their extent. They thus combine the characters of the horns of the giraffe and those of the ordinary antelopes, together with the expanded and branched form of the antlers of the deer. Only the horns of the rhinoceros are composed wholly of horny matter, and this is disposed in longitudinal fibres, so that the horns seem rather to consist of coarse bristles compactly matted together in the form of a more or less elongated sub-compressed cone.' True horny matter," the writer says, "is really a modified form of epidermic tissue, and consists of an albuminous principle termed 'Keratin.' It forms not only the horns of the ox tribe, but also the hoofs, claws, or nails of animals generally, the carapace of the tortoise and the armadillo, the scales of the pangolin, the quills of the porcupine and hedgehog, and the feathers of birds," and I would add to this list the baleen plates of the "Right" whale, which are developed from the skin of the roof of the mouth, and also the whalebone-like hairs of the tail of the elephant.

It must, I think, strike any reflecting zoologist as remarkable that animals so closely allied as the deer and the antelope should present such apparently diverse forms of horn-structure. I propose in this paper to endeavour in some degree to reconcile these apparent differences, and to see whether they are not rather outside differences than of the essential structure of these organs.

If we in the first place take note of the life-history of the horns in these two families of the Ungulata, we shall observe that in the antelopes, as in bullocks, goats, and sheep, the horns grow slowly during the whole life of the animal, while in the deer the antlers are shed and reproduced of a larger size every year; again, that in bullocks and antelopes the females as well as the males are generally furnished with them, while in most of the deer tribe, except the reindeer, they are possessed by the males only.

These two characteristics of the deer tribe seem to indicate that in most of them the horns are not so much required for the defence of the animals against external enemies as to enable the strongest males to get the mastery of the rest, and thus, in Darwinian language, to provide for the "survival of the fittest" in the perpetuation of the race. The antler, then, as a finished weapon, exists only for a limited period of the year, and all through the time of its rapid growth it is unfit to be used as a weapon, being during that time covered by tender hairy skin, which would bleed if roughly struck.

This periodical difference during the time of growth on the one hand and of use as a weapon on the other is associated also with differences of temper and of courage in the stag, the ordinary timidity during growth being replaced by quarrelsomeness and boldness when the fighting organ is complete and when its previously tender skin has died, shrivelled, and begun to peel off. It could scarcely then be expected that with such differences in the rapidity of growth, the structure of the horns should be identical in the deer and the antelope. We have seen above that Owen spoke of the two systems to which the two kinds of horn especially belong, and which I may call, shortly, the *skin* structure and the *bone* structure, and in the case of the deer he refers it to the bony system only. But in truth all horns belong to both systems, for in the deer we see both skin and bone developed during the growth of the antler, and it is only when it is completed as a weapon that it consists of bone only. What, then, during growth is the structure that in the deer seems to correspond homologically with the horny part of the antelope's or bullock's horn? During the rapid growth of the antler there is manifestly not sufficient time for the formation of true horny matter, and the skin is then covered with hair only, which I conceive to be the homologue of the horny part of the bullock's or antelope's horn. In some species used to a warm climate this hair is fine, scanty, and soft; while in others, as the reindeer, which is fitted for a cold climate, the "velvet," as it is called, is often coarse and shaggy.

In the rhinoceros the growth of the horn is quite out of proportion to that of the bone, which simply consists of a slight roughening or knobbing of the bones of the face, which support the horns. Near the hollow base of the horn where it grows from the skin organ, the horny matter can be readily split up into hair-like fibres, and in the horn of bullocks and antelopes generally a longitudinal striation of the surface and of the interior can be traced, which seems to mark its close alliance with hair-structure. In some species of antelope this longitudinal striation is especially marked, as in the serows of India and the chamois of Europe. These hair-like fibres are less apparent in the older part of the tip of the horn, but still they can often be traced from end to end, both in the rhinoceros and in the hollow-horned ruminants generally. In many species of the latter, too, we commonly see various ribbed and knobbed patterns produced upon the surface which often serve to distinguish the particular species or genus from others. These rings and elevations of the surface may, I think, represent a periodical increase of activity in their growth somewhat akin, although in a very minor degree, to the enormous annual growth of the deer's antlers. It seems to me that the old division of the Ruminants into "Hollow-horned" and "Solid-horned" rather tends to obscure the fact that the so-called "hollow" horns are not really hollow, but more or less closely filled during life with a bony supporting core, which is attached to the horny sheath by intervening layers of membrane or skin, which are full of blood-vessels, and often bleed considerably when the core and its sheath are torn asunder by accidental violence.

In Owen's description the horn of the American "prong-buck" is referred to as presenting in combination some of the characters of the horns of the antelope, of the giraffe, and of the deer; and there is another respect in which it seems intermediate between these, in that it is shed periodically like the antlers of the stag; but its horn-core is not prolonged into the prong or single branch which the horn gives off, but is simple like the cores of the horns of the rest of the Bovidæ. The horn of the prong-buck may then be reckoned a true connecting link between the two kinds of horns, viz. those of the oxen and those of the deer.

As this animal, the prong-buck (*Antilocapra Americana*), differs in these and some other respects from the rest of the Ruminants, it has usually been placed by zoologists in a separate section of the Ungulates, viz. the "Antilocapridæ," so called because they seem to connect the antelopes and goats. As correct observations of it have only of late years been obtained, it may be well to describe the horn-growth somewhat more in detail. The horns then, which are present in both sexes, rise vertically above the eyes, are flattened at the sides, and curved slightly backwards at the tips. About the middle of their height they give off a short branch projecting forwards at an angle of about forty-five degrees. The bony cores, it should be observed, on examination are found to be simple and dagger-shaped, without any branching. Again, the prong-buck is unique among cavicorns in shedding the horn-sheaths annually; this generally occurs about the month of October, but in young individuals it may be deferred until January. Mr. Caton, who has given the best account of the growth of their horns, says that in looking into the hollow of a shed horn, it will be seen that the interior contains a number of coarse light-coloured hairs, all of which are firmly attached, while in the lower part many pass completely through the horn. The core is also covered with similar hairs, growing from an investing skin, and he concludes that these hairs must be broken through when the horn is shed. He considers, finally, that the horn-sheath "is nothing more than a mass of agglomerated hairs." On examining the head of a prong-buck from which the horns have been recently shed, it will be observed that the summits of the cores are already capped with small new horns which are quite hard at the tips, but lower down are found to become gradually softer and softer, until the skin investing the core is reached. As the young horny material grows downwards, it becomes gradually more solid, until by the time the base is reached the horn has become a completed weapon. This mode of growth reminds one of that of teeth, generally, which commence as thin scales at the top of the tooth pulp, which pulp becomes in time wholly converted into true tooth substance by the interstitial deposition of earthy salts and the formation of dentinal tubes.

The teeth we know are, like horns, developed from the skin in the first place, although afterwards they may, in the higher reptiles and mammals, be lodged in sockets in the bone of the jaw. In Owen's definition of "Horns," which I have just read, the one-pronged horn of the prong-buck is compared with the antlers of the deer, but, as Mr. Caton has noticed, the prong consists of horny matter only and contains no bony core, and is therefore unlike the "tines" of the deer's antler. The Indian muntjac or kakar, which is a true deer, has a one-pronged antler which is mounted on a long bony pedicle covered by hairy skin, and therefore at first sight seems much to resemble the horn of the prong-buck.

It seems evident, however, from Mr. Caton's description, that the horn of the prong-buck is a less perfect form of horn than that of most other antelopes, and that the horn seems more a mere aggregation of hairs, as he remarks, and that the horny matter is less removed from the condition of hair, which may account for the fact which he mentions, that many of the loose fibres which he noticed inside the shed horn are simply hairs. Again, it will be seen in the prong-buck that when the old horn is shed the bony core remains, whereas in the case of the deer both the hairy skin, or "velvet," and the bony core are in turn shed after the full completion of the antler. In the more specialized deer horn no true horny matter is formed, but when the velvet has dried and become detached it is only the bony skeleton or core which then forms the fighting weapon of the stag. When this weapon is no longer required, first the projecting "burr," or ring at the base, by its growth stops the circulation of blood in the skin, which then dries and becomes detached, leaving the uncovered bony core exposed, which in its turn, by a process of absorption just below "the burr," becomes cut cleanly off, and the antler falls, leaving the animal defenceless and timid, with all his pugnacity gone.

From what I have said above it will be gathered that I regard all these horny structures as really homologous with hair, the production of which is one of the essential offices of mammalian skin. Again, I look upon the slowly growing "core" of the bullock's or antelope's horn as really and structurally corresponding to the enormous outgrowth that periodically adorns the head of most of the stags; and I consider that the different rate of their growth is quite sufficient to account for the apparent difference of structure of the two forms. The ornamental appendages on the top of the head of the giraffe I do not regard as true horns, as they do not by age gain any annual additions, and are, as stated by Owen, simply skin-covered "epiphyses," seated upon the top of the head, and are not fitted to be used as weapons of warfare, and in fact are not so used at all. I think, then, that there is reason to consider that the horns of the Bovidæ and of the rhinoceros are not so dissimilar from those of the Cervidæ in their histological relations as at first sight they appear to be, and that the natural processes in the two cases are not so markedly divergent as we have generally been led to suppose.

Having now, as I hope, shown the close connection of the horns of the Cervidæ with those of the Bovidæ, and the connection of the horns of the Bovidæ with those of the rhinoceros, the similarity of structure of the single or double horn of the rhinoceros with the baleen plates growing from the upper jaw of the "Right" whales is well known to microscopists, and the frayed edges of the baleen plates having been shown to be separate hairs, the whalebone-like hairs or bristles of the tail of the elephant, the well-known modification of hair observed in the quills of the porcupine and hedgehog, or the feathers of birds, all furnish strong evidence of the homology of all these horny structures with each other. They all, in fact, belong to what has been called the "Exo-skeleton," which is developed from the skin, while the horn cores of the Bovidæ and the completed bony antlers of the stag are, I believe, developments from the "Endo-skeleton."

In all true horns, then, I consider that the skin-structure and the bone-structure are combined, although the horn of the rhinoceros would appear to be an exception, owing to the almost entire absence of development of the bony part and the often large and heavy horn being entirely produced by the activity of the skin organ, which not very distantly resembles the organ which in the "Right" whales develops the baleen from the skin of the mouth. In both cases there appears to be not only a growth of hair-like fibres but also of a supporting horny cement (if I may call it so) in which the hairs are lodged, and which in the whales forms also a covering of the baleen plate. If we examine the concave base of a rhinoceros horn we may see that the surface is covered with small pores, which during life lodge minute papillæ of the skin, from which are developed the hair-like fibres of which the horn mainly consists.

The mode of growth of the prong-buck's horn, as described by Mr. Caton, and afterwards observed by Mr. Bartlett at the Regent's Park Gardens, seems quite unique. Instead of all the new growth taking place at the base of the horn, as in all others of the Bovidæ, in this antelope it appears that the annual new formation begins at the top and gradually proceeds downwards until the root is reached; and this different mode of growth appears to be connected with the annual shedding of the old horn-sheaths, which are gradually pushed off by the new ones as they are formed inside the old ones from the skin covering the cores. This *acrogenous* mode of growth, as I have said above, seems much to resemble that of the teeth of mammals, which begin to be solidified at the top, and after the completion of the body of the tooth, the fangs or roots are developed. It seems difficult to correlate this mode of growth in the prong-buck with that observed in the rest of the Bovidæ, in which all the increase takes place at the root only.

Microscopic Vision.

By Edward M. Nelson, P.R.M.S.

(*Read March 26th*, 1897.)

BEFORE beginning the subject for this evening, I wish to thank you for the great honour your President's kind invitation has conferred upon me in selecting me as an exponent of this later development of microscopy. It will be generally conceded that this development owes its inception to Prof. Abbe's unrivalled mathematical and physical researches in the optics of the microscope, which were first brought to the notice of microscopists in this country by your fellow-citizen, the late Dr. H. E. Fripp, whose translations of Prof. Abbe's original papers were published in the *Proceedings of the Bristol Naturalists' Society* in 1875, new series, vol. i. p. 200. A rather full extract from Dr. Fripp's translations appeared in the *Monthly Microscopical Journal* of the same year.*

Two years later they attracted the attention of Mr. J. W. Stephenson (late Hon. Treas. R.M.S.), who, just twenty years ago, brought the subject again before the R.M.S. And in the following year, 1878, Mr. F. Crisp (late Hon. Sec R.M.S.) read a paper to the same effect before the Quekett

* To Dr. Fripp the microscopical world is also indebted for the translation of Prof. Helmholtz' paper on the "Limits of the Optical Capacity of the Microscope," *Monthly Microscopical Journal*, vol. xvi. p. 15 (1876).

Microscopical Club. By these publications, then, all English-speaking microscopists were made acquainted with what is now known as "The Abbe Theory."

We must now pause to investigate what were the ideas concerning the theory of the microscope current at the time the diffraction theory was published. In the first place, Dr. Goring had in 1837 shown by experiments performed on lepidopterous insects' scales, with an early achromatic $\frac{1}{5}$ objective of $27\frac{1}{2}°$ of aperture (an uncemented triple, consisting of two biconvex and one biconcave lenses), that resolution was connected with angular aperture. "The greater the angular aperture the more could be seen," was twenty years ago held to be an axiom. The effect of this was to produce keen competition between the opticians in the production of objectives of the widest angle. This naturally led to the measurement of angular apertures, and out of the measurement of the angle rose the great aperture controversy. Now Prof. Abbe's theory has quite disposed of this question of angular aperture by showing that resolution varies as the sine of the semi-angle and not as the angle itself. Thus in the case of objectives of 54° and 130° of angular aperture an increase of 100% in resolution is obtained by an increase of no less than 140% in angle; but the increase of $9\frac{1}{2}\%$ in an angle of 160° to 175° is accompanied with less than $1\frac{1}{2}\%$ of increase in resolving power. It was the popularizing of facts like these derived from the Abbe theory that put an end to "the battle of the objectives." No one now-a-days would think of paying £10 to £15 for an extra 5° in a wide-angled objective. Further, the exposure of the fallacy of the utility of objectives possessing enormous initial magnifying power is also due to the Abbe theory, consequently $\frac{1}{25}$, $\frac{1}{35}$, $\frac{1}{50}$, $\frac{1}{60}$, $\frac{1}{80}$ of limited apertures are extinct as the dodo. Allow me for the moment to separate two parts of the Abbe theory, merely for the sake of illustration; the two parts being physically connected together, they must in the nature of things be indivisible, but their supposititious separation will aid us in tracing the sequence of events.

The two parts are, of course, the aperture question and the diffraction theory. The aperture question was the subject of the great controversy that took place in the *Monthly Microscopical Journal*, and a very interesting literature it is from a historical point of view. The disputants were Dr. Pigott, Mr. Wenham, R. B. Tolles, Col. Woodward, the Rev. S. L. Brakey, and others. The controversy began with a paper by Dr. Pigott in the *M.M.J.*, vol. iv. p. 20 (July, 1870). Although the author in this paper put forward his views in such an objectionable form that they called forth just and severe criticism in their day, nevertheless there were in them the germs of some of the great developments that have since taken place. On page 26, for example, we have a small edition of the table of corresponding angles now published on the cover of the *R.M.S. Journal*. The balsam or crown glass angles he characteristically calls "nascent angles." This paper is continued in the September No. (1870), vol. iv. p. 134, and there we find a plate showing the advantages of the immersion system. Fig. 1 shows rays traced from a radiant in balsam through the cover glass into water and then into the lens front; the resultant longitudinal aberration is depicted by the rays being traced backward to the axis in the usual manner. This Dr. Pigott calls the compensating action of "Hydro-spherical Aberration." Now, as the tracing shows only the aberrations arising from the passage of the rays through two plane surfaces, it is evident that the Doctor, in his eagerness to air his Greek, has forgotten the meaning of the word spherical. This figure is contrasted with the next, which is said to show "Aëro-Spherical Aberration." Here the rays are traced from a radiant similarly placed through the air film and into the flint glass of the ordinary double front of a dry objective, and here again we have the aberration due merely to the two plane surfaces. No spherical aberration is illustrated in those figures, but only those aberrations arising from plane surfaces; these aberrations are shown to be ever so much greater in the case of the dry double front than in that of the immersion single front. In practice, however, the very reverse is the case, because if the proper curves were given to the dry objective front, the total aberration arising from the two spherical as well as the plane surfaces would be less than that of the water immersion. For in the single-fronted immersion objective the idea was then, and is now, to compensate the under-correction of the front by the over-correction of the backs: whereas in the old dry lenses the aim was to correct the aberrations as far as possible in each separate combination of the lens, hence the *raison d'être* for triple fronts. In this paper Dr. Pigott proposes the use of turpentine as an immersion fluid, because its refractive index is near that of crown glass or balsam. This is, so far as I am aware, the first suggestion of what is now known as homogeneous immersion.

We see, therefore, that in the midst of much error Dr. Pigott gave to the world several important truths, viz.:—

1. That a water-immersion lens can have a greater aperture than any dry lens, and similarly a homogeneous than a water immersion.

2. That illuminating power is increased by the use of higher refractive media; and

3. The suggestion of homogeneous immersion.

It is refreshing to turn from the pedantic writings of Dr. Pigott to the manly utterances of the Rev. S. Leslie Brakey. If language be defined as a means of enabling others to understand the speaker or writer's thoughts, then S. Leslie Brakey has the gift of language in no small degree, for in the whole of the *R.M.S. Journals* nowhere do we meet with such simplicity of style, clearness of expression, and masterly handling of the subject. Not only is Mr. Brakey a literary scholar, but he shows himself to be a mathematician of no small power. But strange as it may appear, Dr. Pigott is in the main right, while Mr. Brakey is wrong.

The following passage from one of Mr. Brakey's letters will show you what his opinion of Dr. Pigott's paper was:—

"I have said that the question was obscured by the introduction of things irrelevant. The history of Claudius Ptolemy is no more to the point than the history of Claudius Cæsar or Claudius Lysias. No more are the laws of refraction and reflexion, repeated (for about the twentieth time), because these laws are 'first truths,' and are known to every one, and never are, nor ever have been, denied by any one great or small. There is, no doubt, a sense in which this or any other optical question may be said to depend upon them; the same sense in which we may say that a question about the nutation of the earth's axis or the motion of the moon's apse depends upon the multiplication table. These laws are brought in on every occasion with much arithmetic and mathematics done with Greek. This display of learning seems to have impressed his readers so much that even skilful observers fear to trust their own faculties against mathematics so original and profound. No doubt it is very hard for non-mathematical microscopists to think so,—to believe that so much mysterious mathematics can have nothing in it, especially after their nerves have been shaken by meeting such words as Pneumo-spherical and Hydro-spherical, Aberrameters, Kratometers, Refractometers, Eidola, and all the rest. But so it is. The whole of this 'original' learning from beginning to end, the picture of the bent oar not excepted, is simply copied out of the first pages of the little books for beginners, the primers and horn books of optics. Examples are given in the primers to be worked out, and Dr. Pigott works out other examples with the numbers changed,—that is all. The 'original' part is that he works them with infinitely more trouble than is needed."

Enough has been said to put you in a position to judge of the state of microscopic optics at that time (1870–71). But before passing on, it may be as well to point out that it is more than possible that this hint of Dr. Pigott's of turpentine immersion (homogeneous as regards refractive index, but irrational as regards dispersion) suggested to R. B. Tolles the balsam immersion objective which he had in 1874 actually constructed. Tolles being a practical optician, must have known that turpentine had far too high a dispersive power to be of any use for immersion purposes.

The correct principles underlying the measurement of apertures had been investigated and published by Tolles,[1] who later, in March, 1873,[2] was the first to describe an apertometer, consisting of a semi-circular disc with slides, much the same as that now known as Abbe's Apertometer. Apertures in those days were measured by angles in glass

[1] *M. M. J.*, vol. vii. p. 117, fig. 1 (1872).
[2] *M. M. J.*, vol. ix. p. 213, Pl. xv. (March, 1873).

or balsam, and were called balsam angles. The word "Homogeneous" as applied to immersion objectives is probably due to Tolles,[1] for he says, "Fig. 1 represents a section of two hemispherical lenses balsam cemented, with a diatom or other small object at the centre, together constituting a nearly homogeneous transparent globe."

We must now leave the aperture question, and see what was the state of the diffraction theory at that period. The originator of the diffraction theories, both telescopic and microscopic, was Frauenhofer, who, in 1821, ruled fine gratings and measured the angular deviation of the diffracted beams with a twelve-inch theodolite. From the measurements thus obtained he deduced the now well-known laws in $\theta = \frac{\lambda}{\delta}$ when θ is the angular divergence of the diffracted beam, λ the wave length, and δ the value of a line and interspace. From this equation he inferred that the limit of microscopic vision was reached when δ was equal to λ; in other words, when the line and interspace equalled the wave length sin θ became unity and θ equal to 90°.

Of course Frauenhofer knew nothing about oblique light or immersion objectives, so that statement was substantially accurate in his day. If you try the experiment, you will find that you will be unable to resolve 48,000 lines per inch with a wide-angled dry objective, when using a perfectly parallel axial beam. Sir John Herschel, in 1827, said that he was doubtful about the accuracy of Frauenhofer's conclusions. Nobert, the celebrated test-plate ruler, took up this question in 1852; he, however, does not seem sure of his ground, for he says, "I am therefore very anxious to learn whether in resolving the lines of the test plate we shall be able to progress beyond the 15th band." In the *M. M. J.*

[1] *M. M. J.*, vol. vi. p. 214 (1871).

vol. ii. p. 291 (1869) there is a figure on a fly-leaf illustrating some remarks on the Frauenhofer theory by Dr. Barnard, the President of Columbia College, to whom Col. Woodward had referred the question. This figure supplies one of the points missing in Frauenhofer's argument. That argument was, as we have seen, defective in these two respects: first, no account was taken of oblique light; secondly, there was no provision made for media other than air. Now, this figure of Dr. Barnard's supplies the first of these omissions by giving the paths of the diffracted beams arising from a pencil of parallel rays falling obliquely on a grating. Dr. Barnard disagrees with Frauenhofer's conclusions, and says, "With an objective that takes in a cone of an angle of from 140° to 175°, it is nonsense to talk of this question as one settled by theory." He then goes on to say that if Frauenhofer's theory is correct, not even the 9th band of Nobert's 19th band test-plate (56,300 lines per inch) could be resolved in monochromatic yellow light. Col. Woodward states that at the time he had received Dr. Barnard's letter he had resolved up to the 18th band and subsequently the 19th with a P. and L. water immersion $\frac{1}{16}$. So we see that although these two eminent men had a correct picture before them, they were unable to perceive its significance.

In fine, Col. Woodward's successful photographs had so completely shattered the Frauenhofer theory that it was not worth further consideration. You have now before you the opinions of microscopists both as to aperture and diffraction, at the time when the diffraction theory of microscopic vision as demonstrated by Abbe and Helmholtz was given to this country by Dr. Fripp. It will be unnecessary for us to make any prolonged examination of the Abbe theory, for all are familiar with it, as it has been frequently republished since Dr. Fripp's time. We can, however, pause to discover what new views were added to microscopy by it. First, as regards aperture, we have seen that before the publication of the theory the angular aperture of objectives had been correctly measured, and the angular apertures of dry, water immersion, and balsam immersion objectives had been correctly compared; the balsam angle being the then standard of comparison. Prof. Abbe's very brilliant idea of using one limb of Snell's equation (law of sines) as a standard to which all kinds of aperture might be referred greatly simplified matters, and at the same time put fresh meanings into, and enlarged the ideas connected with, the term aperture. We see, therefore, that both Dr. Pigott and Tolles used numerical aperture in the conversion of their angles (nascent angles, Pigott; balsam angles, Tolles), but they did not call it by that name. They used Snell's law; thus, $\mu \sin \phi = \mu' \sin \phi'$; Abbe went further and said, $\mu \sin \phi = \mu' \sin \phi' =$ Numerical Aperture. Tolles, in measuring a dry $\frac{1}{4}$, might have observed an angle of $27\frac{3}{4}°$ in his glass apertometer where $\mu = 1{\cdot}52$. He would then have looked out the sin of $27\frac{3}{4}°$, viz. ·465, and have multiplied it by 1·52, obtaining the product ·707; he would then have been proceeding to convert this sine into an angle, when Prof. Abbe would have interposed and said, "Stop, that is Numerical Aperture; do nothing further." If Tolles had gone on, he would have found that ·707 was the sine of 45°, and the angular aperture of his $\frac{1}{4}$ would consequently have been 90°.

As to the enlarged ideas put into the word Aperture by Prof. Abbe, time will only permit of an examination of these in outline. Any one wishing to pursue this interesting subject further can easily do so by consulting current publications.

1. The photometric value of the term.

The radiation of light from any surface diminishes in proportion to the cosine of the inclination of the rays to the normal. This fact may be easily demonstrated by the uniform illumination of a gas globe, for if beams radiating obliquely from the surface were as luminous as similar beams radiating normally, the consequence would be that the peripheral portions of the globe would be far brighter than its central portion. If, for example, we were to cover a spherical football with postage stamps, we should see a great many more postage stamps at the periphery, where they would be inclined obliquely towards us, than in the centre, where they would be in a plane perpendicular to the line of sight. Now if each postage stamp sent one ray to the eye, and the oblique rays were equal in intensity to the direct rays, the periphery must appear much brighter than the centre. But such is not the case; spherical objects when uniformly illuminated appear equally bright all over, therefore the emission from every point of their surfaces must diminish in the proportion of the cosine of the inclination of the ray to the normal. This means that the amount of light radiating from a point in a homogeneous medium varies as $(\sin u)^2$ the square of the sine of the semi-angle of the solid cone. The next point is that the radiation of energy such as light or heat in different media varies as (n^2) the square of the refractive index of the media. Therefore the total effect of radiation in any medium is proportional to $(n \sin u)^2$, that is, the square of the numerical aperture.

We now come to that which may appropriately be called the Magna Charta of Microscopy, or the Lagrange, Helmholtz, Abbe theorem.

Let u and u' be the angles of convergence of any ray on either side of a given system, n and n' the refractive indices of the media on either side, and M the magnifying power; then—

Lagrange (1803) showed that $\frac{u}{u'} = M$, the media on both sides of the system being the same and the aperture small.

Helmholtz (1866) that $\frac{n}{n'}\frac{u}{u'} = M$, the media different but the aperture small.

Abbe[1] (1873) that $\frac{n}{n'}\frac{\sin u}{\sin u'} = M$, for any aperture or media.

Prof. Helmholtz[2] also proved this last result, but was preceded in publication by Prof. Abbe by six months.

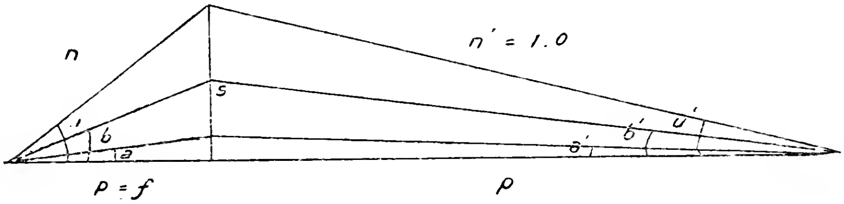


Fig. 1.

The following is a condensed epitome of the proof. Let p and p' be two conjugate points on the axis, and let u represent the angular divergence of an immergent, and u' the convergence of an emergent pencil; and a, a', very small angles with the same significance. Let air be on both sides of the system. When p' is large, $p = f$ very nearly. Then if s is the semi-aperture, $\frac{s}{p} = \tan a$; and

[1] Prof. Abbe's theorem, *J. R. M. S.*, ser. ii. vol. i. (1881), p. 392. *Vide* also an interesting paper, *J. R. M. S.*, vol. iii. (1880), p. 509.

[2] Prof. Helmholtz' theorem, *Proceedings Bristol Nat. Soc.*, New Ser., vol. i., part 3; and in *Monthly Microscopical Journ.*, vol. xvi. (1876), pp. 22, 25, 26.

$\frac{s}{p'} = \tan a'$; therefore $\frac{\tan a}{\tan a'} = \frac{p'}{p} = \frac{p'}{f}$; as the angles are so small the angles may be written for their tangents thus—

$$\frac{a}{a'} = \frac{p'}{f} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(i.)}$$

We have seen that radiation in different media varies as (n^2), the square of the refractive index, (this was demonstrated by Prof. R. Clausius in 1864,) and therefore the radiation for a small plane angle a in any medium will vary as $n\,a$. So when there are different media on either side of the lens formula (i.) becomes $\frac{n\,a}{n'a'} = \frac{p'}{f}$; but in the microscope n' is always 1·0 for air, therefore

$$\frac{a}{a'} = \frac{p'}{n\,f} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(ii.)}$$

Now the law of convergence for aplanatic systems, to which images formed by wide-angled pencils conform, is the equality of the ratio of the sines of the angles of the inclination of conjugate pencils to the axis. Thus, let a be a very small angle, as before, and b, c, ... u increasingly larger angles of inclination of incident pencils to the axis, and a' b' c' . . . . . . u' those of the emergent pencils, then

$$\frac{\sin a}{\sin a'} = \frac{\sin b}{\sin b'} = \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \frac{\sin u}{\sin u'} \quad . \quad . \quad . \quad . \quad . \quad \text{(iii.)}$$

In the case of the very small angles we may suppress the sine and write the angle itself, thus by (ii.).

$$\frac{\sin u}{\sin u'} = \frac{a}{a'} = \frac{p'}{n\,f} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(iv.)}$$

Above we had $p' = \frac{s}{\tan u'}$; now as u' in the microscope with its present nosepiece cannot exceed about 3°, we may legitimately write the sine for the tangent, thus—

$$p' = \frac{s}{\sin u'}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (v.)$$

Inserting this in (iv.) we have—

$$\frac{\sin u}{\sin u'} = \frac{s}{nf \sin u'}, \text{ or } n \sin u = \frac{s}{f}. \quad . \quad . \quad . \text{ (vi.)}$$

That is, the numerical aperture is the ratio of the semi-aperture to the focus.

Another conclusion may be arrived at, for $\frac{p'}{f} = M$ very nearly; putting this value in (iv.) we have $n \sin u = M \sin u'$, viz., the proof of the proposition as it was stated in the beginning.

Numerical aperture has so entirely superseded angular aperture that few microscopists nowadays know the angular aperture of their objectives.

From (vi.) the following useful formulæ may be derived:—

$\frac{\frac{1}{2} \text{ back lens}}{N.A.} = f$. This is a simple way of measuring the equivalent focus of any objective.

Because $f = \frac{p'}{M}$ very nearly, $\frac{M \times \frac{1}{2} \text{ back lens}}{\text{distance}} = N.A.$

This is useful because it enables the *N.A.* of any objective to be measured without an apertometer. The image of a stage micrometer is projected without an eyepiece on a screen say 2 or 3 ft. from the back lens, and *M*, the magnifying power, is measured; this, when multiplied by half the diameter of the back lens, and the product divided by the projection distance, gives the *N.A.*

We now come to the Diffraction Theory. Prof. Abbe's experiments with gratings and spectra are so well known to you that repetition is unnecessary. By means of these experiments Prof. Abbe has demonstrated that the resolving power of a microscope objective depends on its capability of picking up certain pencils that have been scattered by diffraction. We have seen that diffracted beams diverge in air according to the Frauenhofer law $\sin u = \frac{\lambda}{\delta}$, and in any medium as $n \sin u = \frac{\lambda}{\delta}$. We are now in a position to make a great generalization, viz., that the expression "Numerical Aperture" or $n \sin u$ is the correct measure of the aperture of a microscope objective. First, because it is equal to the ratio $\frac{s}{f}$ or semi-aperture to focus. Secondly, because the radiation of light in a plane angle in any medium is measured by $n \sin u$. Thirdly, because $\delta = \frac{\frac{1}{2}\lambda}{n \sin u}$, which means that the extreme resolving limit of an objective is in the ratio of half the wave length to $n \sin u$.

By comparing this state of knowledge with that which existed before the publication of Dr. Fripp's translation of Prof. Abbe's papers by the Bristol Natural History Society, we are able to precisely estimate the great benefit Prof. Abbe has conferred on the microscopical world. Angles had been correctly measured, and air, water, and balsam angles had been correctly compared before Prof. Abbe had published anything on the subject; but the correct and full ideas of aperture in contradistinction to mere angle, and all the important corollaries that flow from those views, are entirely due to Prof. Abbe.

We must, however, return to the diffraction theory because it was not free from error when it was first enunciated, and it was no doubt often wrongly interpreted.

Prof. Abbe stated that the image in the microscope had a twofold origin ; for whilst coarse structure was imaged according to the ordinary dioptrical laws of light, the image of the fine structure was dependent upon diffraction phenomena, the investigation of which lay rather in the region of physics than of geometrical optics. The line of demarcation between coarse and fine structure was placed at $\frac{1}{2500}$ inch ; therefore all objects larger than that size were dioptric or absorption images, and all smaller ones were diffraction images. This position is a wholly untenable one, for the diffraction pencils arising from gratings, such as wire sieves, linen threads, ruled scales, etc., where the intervals are, at the least, $\frac{1}{50}$ inch, can be easily seen without any special apparatus. With suitable apparatus the spectra arising from much larger gratings have been made visible.

The two following are simple, though very important experiments which prove that the Frauenhofer diffraction law applies even to large objects which can be seen without instrumental aid.

1. When a scale on a carpenter's rule is examined through a diaphragm, held close to the eye, the hole in it being ·011 inch in diameter, some divisions on the rule can just be perceived at $7\frac{1}{2}$ inches ; what is the fineness of the divisions ?

Let a be the diameter of the hole, and λ the wave length, say $\frac{1}{45000}$ inch, δ being the value of one line and interspace. Then $\frac{a}{7{\cdot}5}$ will be the angle the hole subtends at the distance of the scale. By the Frauenhofer law u, the divergence of the diffraction beams is such that $\sin u = \frac{\lambda}{\delta}$, but in order that two diffracted beams may just pass through the hole which is the condition of the limit of visibility of the grating, sin u must also $= \frac{a}{7\cdot5}$, therefore $\frac{\lambda}{\delta} = \frac{a}{7\cdot5}$, and $\delta = \frac{7\cdot5\lambda}{\cdot011} = \frac{1}{66}$ inch. The scale actually had 64 lines per inch.

2. The converse problem may be treated in a similar manner. Looking through a hole in a diaphragm, placed close to the eye, a scale of 50 lines to the inch can be just perceived at a distance of 9 inches. What is the diameter of the hole? The hole subtends an angle of $\frac{a}{9}$ at the scale; this angle must be equal to sin u, if the grating is just resolved. Therefore, $\sin u = \frac{\lambda}{\delta} = \frac{a}{9}$; $a = \frac{9\lambda}{\cdot02} = \cdot01$ inch. The actual size of the hole by micrometric measurement was ·011 inch.

Prof. Abbe summed up the results of his experiments on the diffraction image in these words:[1]—

"Everything visible in the microscopic picture which is not accounted for by the simple absorption image, but for which the co-operation of groups of diffracted rays is needed —in fact, all minute structural detail—is, as a rule, not imaged geometrically, that is conformably with the actual constituent detail of the object itself. However constant, strongly marked, and, so to speak, materially visible, such indications of structure may appear, they cannot be interpreted as morphological, but only as physical characters; not as inages of material forms, but as signs of certain material differences of composition of the particles composing the object. And nothing more can be safely inferred from the microscope revelation than the presence in the object of such structural peculiarities as are necessary and adequate to the production of the diffraction phenomena on

[1] *Monthly Microscopical Journal*, vol. xiv. (1875), p. 249.

which the images of minute details depend. From this point of view, it must be evident that the attempt to determine the structure of the finer kinds of diatom valves by morphological interpretation of their microscopic appearances is based on inadmissible premises. Whether, for example, *Pleurosigma angulatum* possesses two or three sets of striæ; whether striation exist at all; whether the visible delineation is caused by isolated prominences or depressions, etc., no microscope, however perfect, no amplification, however magnified, can inform us."

This passage means that when you are dealing with objects not less than $\frac{1}{2500}$ inch in size, the microscope image is to be trusted; but with regard to structures of a smaller size than this, because they are imaged diffractionally, we have no warrant in asserting them to be morphologically accurate. Now, the experiments given above show that the diffraction limit is at least fifty times greater than that assumed; the figures, therefore, in the preceding paragraph must be altered to $\frac{1}{50}$ inch, from which it follows that the only microscope images to be accepted as truthful are those of objects larger than the $\frac{1}{50}$ inch: a conclusion which we know to be absurd.

There was another conclusion derived from the diffraction theory which was fraught with far greater danger because it introduced erroneous methods of working the microscope. It was said, because the image of fine structure depends upon spectra, therefore make spectra.

By this not altogether clear phrase, it was meant that the spectra which can be readily seen when the eyepiece is removed should be made as bright as possible by reducing the aperture of the illuminating cone. Reducing the aperture of the illuminating cone is analogous in its effect to closing the slit of a spectroscope, for if the slit is too wide there is an over-lap in the spectra, and the spectrum becomes impure; so, too, by opening out the illuminating beam there is an overlap of diffraction spectra, and they become so impure that finally all colour is lost. Narrow the illuminating beam to a mere point and the spectra from any diatomic structure will become brightly coloured. (So much is this the case that if a spectroscope is not at hand a coarse diatom such as a *pinnularia* illuminated by a narrow cone when a suitable objective is employed makes a very good substitute, and a monochromatic screen or a light filter of any kind can be tested by examining the spectra at the back of the objective, when the eyepiece is removed.) This is no means an old fallacy, for one of Prof. Abbe's last papers, if not the last, is for the purpose of advocating the employment of a narrow cone. He says,[1] "The resulting image, produced by means of a broad illuminating beam, is always a mixture of a multitude of partial images which are more or less different (and dissimilar to the object itself). There is not the least rational ground—nor any experimental proof—for the expectation that this mixture should come nearer to a strictly correct projection of the object (be less dissimilar to the latter) than that image which is projected by means of a narrow axial illuminating pencil. This latter image has the most favourable conditions in regard to similarity to the object, because in its production nothing is lost of the diffraction-pencil but the peripheral portions (which in most cases are of relatively small intensity)."

This authoritative statement, backed as it is by so great a name as that of Prof. Abbe, is most damaging to the interests of microscopy. For, apart from the question of the manufacture of false images, it renders unnecessary any improvement in the objective. The quality of an objective

[1] *Journal R.M.S.*, 1889, p. 723.

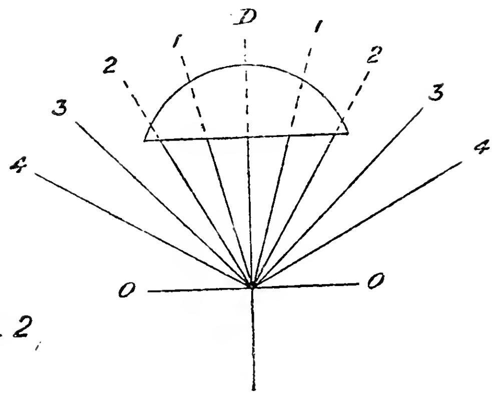


Fig. 2.

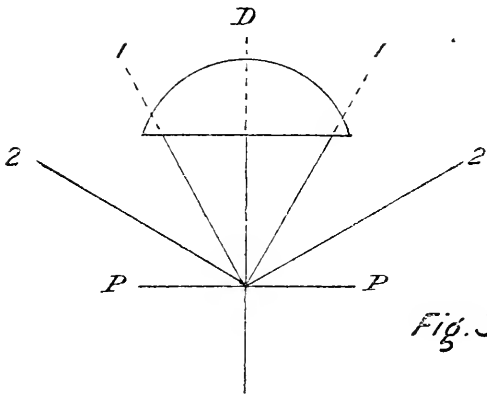


Fig. 3.

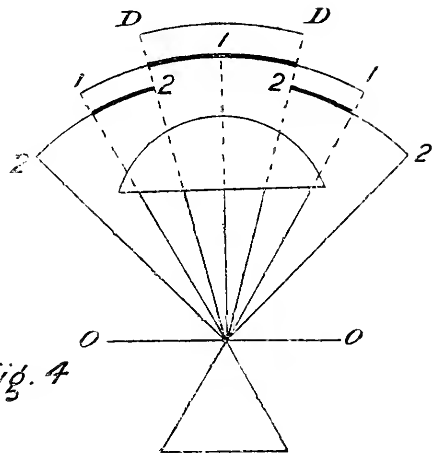


Fig. 4.

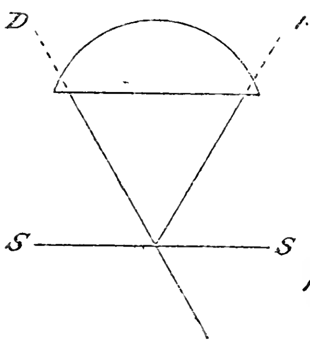


Fig. 5.

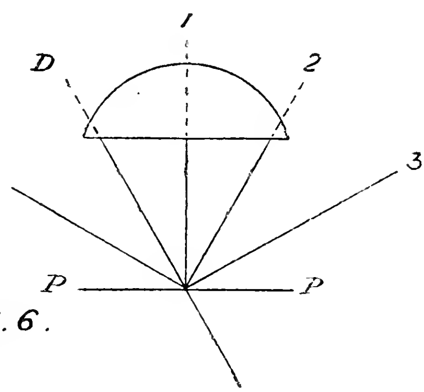


Fig. 6.

depends on its capability of standing a large cone of illumination, and the difference between a really fine objective and a mediocre one is that the fine objective will stand at least $\frac{3}{4}$ of its back lens being filled with light, while the mediocre one will not; so then if wide cones of illumination are injurious, and only narrow cones are to be used, it follows that mediocre objectives are quite as good as those of the first class, because with a narrow cone it is impossible to tell the difference between them. Important as this is from a brass and glass point of view, it sinks into the shade in comparison to the manufacture of false images by use of a narrow cone.

As there is a diversity of nomenclature in use in matters appertaining to these discussions, it will be as well first to clear the ground of all ambiguity. The central white beam, sometimes called the "central maximum," will be called the dioptric beam (*D*); the first coloured spectrum next the dioptric beam will be called the spectrum of the 1st order (1); the one next to that will be called a spectrum of the 2nd order (2), and so on; see Fig. 2.

The law, then, for the manufacture of the simplest form of false image, is the union of a spectrum of the 2nd order with the dioptric beam, when that of the 1st order is suppressed. In this case the false image will consist of a doubling of line structures, and the insertion of an intercostal in hexagonal and similar structures. To repeat,—the cause of the false image is the suppression of the 1st order spectrum, and not merely the admission, *per se*, of that of the 2nd order; for if the 2nd is admitted and combined with the dioptric beam, the 1st also being combined with them, there will be no false image. The suppression of spectra of the first order may be easily accomplished by placing a suitable stop at the back of the objective; there is, however, another and far more common way of doing it without any stop, and that is by using a narrow con. When a narrow axial cone of illumination is used, spectra of the first order pass through an intermediate zone of the objective aperture, whilst those of the 2nd order pass through an outer zone (Fig. 2); then spherical aberration (which is always present, even in the best objectives, to a far greater extent than is generally supposed) will cause spectra of the 2nd order to be combined with the dioptric beam *D*, to the exclusion of those of the 1st order, thereby forming a false image. Putting it in a popular form, it may be said that the eye is quite unable to distinguish whether any given spectra are spectra of the 1st order arising from a fine structure (*P*, *P*, Fig. 3) or spectra of the 2nd order from a coarse structure (*O*, *O*, Fig. 2); so that if spectra of the 2nd order and the dioptric beam, *D*, are brought into focus together, while spherical aberration is causing the spectra of the 1st order to be out of focus, the result is that the eye interprets the spectra of the 2nd order of the coarse structure (*O*, *O*, Fig. 2) as if they were spectra of the 1st order of fine structure (*P*, *P*, Fig. 3), consequently a ghost image of fine structure is seen. If, therefore, the coarse structure (*O*, *O*, Fig. 2), which in this instance would be the true image, had a certain number of lines or marks to the inch, say 12,000, then the ghost image would have precisely double that quantity, or 24,000 to the inch.

False images of greater complexity may be made by combining spectra of the 3rd order with the dioptric beam *D*, when those of the 1st and 2nd orders are excluded, etc.

All these false images are dispelled by means of the wide-angled axial cone of illumination (*i.e.* $\frac{3}{4}$ cone), because it causes groups of spectra of the 1st order to pass through the same zone of the objective as those of the 2nd order, and unites as well portions of the 1st order with the dioptric beam *D* (Fig. 4), thus rendering their separation impossible.[1]

There is another form in which the small cone is met with, viz. "oblique illumination."

This kind of illumination is very old, and was probably invented by Dr. Goring,[2] who in 1826 found that by means of oblique light lined tests could be resolved more easily. By oblique illumination is meant illumination by beams in one or two azimuths, inclined more or less to the axis of the microscope. Often the inclination of the illuminating beam is so great, that it only just falls within the grip of the objective; if its obliquity were a little greater, the object would appear illuminated on a dark ground. With oblique illumination the dioptric beam passes through a marginal zone on one side, and when the structure *S*, *S*, 48,000 per

[1] In Fig. 4 the dioptric beam and the spectra of the 1st and 2nd orders are distinguished by being drawn in steps, those portions which overlap being indicated by thick lines. The structure *O*, *O*, is supposed to have 12,000 lines or marks per inch, and to be similar to that in Fig. 2. *P*, *P*, in Figs. 3 and 6, are supposed to have 24,000 lines per inch, while *S*, *S*, in Fig. 5, has 48,000. In these figures the refraction of the lens has not been represented. The lenses have merely been inserted to show the position of the spectra with regard to them.

[2] "On Mr. Tulley's thick aplantic object glasses for diverging rays: with an account of a few Microscopic Test objects by C. R. Goring, M.D." *Quarterly Journal of Science, Literature and the Arts*, Dec., 1826. In vol. xxii. of *The Journal of the Royal Institution*, published 1827.

NOTE.—Mr. Tulley (also spelt Tully), the celebrated telescope maker, was the first to construct (in 1824) a *successful* achromatic microscope object glass in this country. It was a single uncemented triple combination composed of a biconcave flint enclosed between two biconvex lenses, one being of crown, and the other of plate glass. It was ·9-inch focus, and ·16 N.A. in aperture.

inch, is only barely resolved the spectrum of the 1st order passes through the same zone on the opposite side (Fig. 5); therefore, under these conditions, as there is no spectrum of the 2nd order admitted, it is impossible to duplicate the structure. Although the image of the object probably will be ill defined and defective in certain particulars, it will, however, be correct with regard to the fineness (48,000 per inch) of the structure delineated. When, however, the structure is sufficiently coarse (24,000 per inch) to enable a spectrum of the 2nd order and the dioptric beam to pass through the marginal zone (Fig. 6), a spectrum of the 1st order will pass through the centre of the objective; spherical aberration will prevent this 1st order spectrum combining with the dioptric beam and the 2nd order spectrum situated in the marginal zone, consequently an image of a structure having double the fineness (*i.e.* 48,000 per inch) of the original will be seen. Thus, for example, if the original structure consists of a net having 24,000 meshes per inch, the image will be that of another net having 48,000 meshes per inch. We have confined ourselves to lines and diatom markings in the preceding discussion, because with such objects demonstration becomes easier, but the laws apply to all objects; some biological objects upon which theories have been based are of the nature of false ghosts, or, in other words, are merely the duplications of entities.

It is the duty of every microscopist therefore, be he a biologist or a physicist, to critically examine the conditions he is working under, and so make sure that those conditions are such as will not permit the separation and isolation of groups of spectra of various orders by the spherical aberration of the objective.

Some tests may be applied to determine whether the structure in question is, or is not, a false ghost.

1st. They usually occur when a small cone of illumination is employed.

2ndly. They must be an integral multiple of some real structure; thus, if the real structure is 12,000, the ghost may be 24,000, 36,000, or 48,000, etc.; but it can never be 18,000 or 30,000.

3rdly. The ghosts invariably have a focus differing from that of the true structure. Thus the false structures may appear to be above or below the real structure; the position depending upon the over—or under—correction of the objective.

A question will naturally arise, What is the resolving power when a $\frac{3}{4}$ axial cone of illumination is used?

The answer is, 70,000 times the N.A. of the objective; it will then be said that this is only 73% of the amount given as the resolving limit in the tables published in the *Journal of the Royal Microscopical Society*. In reply, it may be pointed out that the limit given in the tables in the *R.M.S. Journal* is the limit of resolving power when a narrow illuminating beam of extreme obliquity is employed, and that this limit is twice the wave length multiplied by the Numerical Aperture, or 96,000 times the N.A.

Although this is perfectly true theoretically, yet practically it is not so, for many delicate resolutions which cannot be seen at all with oblique illumination are visible with the $\frac{3}{4}$ cone; and further, the narrow oblique beam is a fruitful source of false images.

It may be next pointed out that the plan of using light of a shorter wave length does not give the advantages that theory would lead one to expect. With a $\frac{3}{4}$ cone it is found that the resolving limit for light in the region of the F line is 80,000 times the N.A., but that this gain ceases when objectives which have a higher N.A. than 0·8 are employed.

Therefore for objectives of 0·9 N.A. and upwards it is necessary to revert to the 70,000 times the N.A. limit.

We now come to a very important point; viz., the "black and white dot." This term is used to express the fact that when an object—such, for example, as a siliceous plate—is viewed under the microscope, its edge assumes either a black or white appearance, according to changes in focus; but when we have the edge an inner edge of a hole, then when the hole is very minute the black edge on one side of the hole will meet the black edge on the opposite side, and the hole will appear as a "black dot"; but when the focus is arranged so as to give a white edge, then the hole will, by a similar argument, become a "white dot."

This is a phenomenon perfectly familiar to diatomists, who are accustomed to study the minute holes in the siliceous valves of diatoms; hence the origin of the somewhat curious name given to this phenomenon of "black and white dot."

Although this term was primarily applied to diatoms, it is applicable to all minute microscopical objects, such as bacteria, hairs, flagella, and the edges of objects generally.

Now there is a curious point about this phenomenon, which bears on the subject under discussion this evening; viz., that the visibility of the "black and white dot" depends upon the aperture of the objective, because the greater the aperture the easier it is to obtain a "black dot." When, however, the hole becomes excessively minute, a "black dot" is no longer attainable, and we have to content ourselves with the "white dot" appearance.

There is nothing in the theory of microscopic vision, as at present enunciated, to account for this fact, that a larger aperture is required to resolve the "black" than the "white dot" image.

This becomes an important point when dealing with the limit of microscopic vision, because the question will naturally arise, What limit, the "black" or "white dot" limit? For obviously there must be two limits.

There is another, and perhaps a more important, question; viz., Which of the two is the more correct picture? Moreover, as these images occur at different foci, a further question arises, What is the correct focus? and on this hangs the last question, for the adjustment of the objective depends on the focus, What is the correct adjustment?

We now come to the last point; viz., dark ground illumination. This illumination is best obtained by placing an opaque stop at the back of the condenser, to stop out an axial cone of greater aperture than that of the objective on the nose-piece. Now it is found in practice that with this kind of illumination, when the ground is strictly dark, that the resolving limit of all objectives is lowered; the diffraction theory, however, offers no explanation of this phenomenon.

When the stop at the back of the objective is hardly large enough, the ground assumes a pearly appearance; in this case the resolving limit is at its maximum.

You have been detained long enough over this technical and very dry subject, but the remarks made this evening will not have been in vain if they induce any member of your Microscopical Society, upon whom Dr. Fripp's mantle may have fallen, to take up this subject and work out the answers to these questions. Any one doing so will, I am sure, earn the gratitude of all genuine students of "Microscopy."

A Few Observations on Local Surface and Underground Springs and their Surrounding Strata.

By H. W. PEARSON, M. Inst. C.E., M.I.M.E.

(*Read May 4th*, 1897.)

BEFORE I commence my few remarks I think a word of explanation is due from me for appearing before you to-night, as my subject is not purely one in which your Society takes most interest; but perhaps I may be excused for so doing when I say that it was at the invitation of the President of the Bristol Microscopical Society, Mr. Stoddart (while having a chat with him upon Water questions), that I undertook to put on paper a few remarks, and as the charter of an engineer is defined as one who "directs the power and sources of nature for the use and convenience of man," I am therefore in that capacity somewhat closely connected with Nature's many wonderful and instructive subjects.

The subject of my paper is not, as you will gather, so closely connected with the more beautiful and charming in nature compared with the subjects you are in the habit of discussing; but in its connection with geology and the opening out of the resources of nature for man's study, enjoyment, and convenience, it may, perhaps, be considered to tread upon the threshold of a naturalist's scope of inquiry.

The presence of natural and healthy germs and organisms which are to be found in springs and rivers and are really nascent in water, are doubtless better known, and have been treated upon, by you in your many researches, inasmuch as you have amongst your number eminent chemists, biologists, and physiologists, and last, but not least, a gentleman who stands high in the geological world, viz. the President of the College, Professor L. Morgan. I shall not, therefore, attempt to travel into that area of inquiry.

Engineering geology (if I may so term it) is what every civil and, more especially, hydraulic engineer must gain more or less knowledge upon as he carries out his work of dealing with water and water supply.

The origin of surface springs, which have their natural outlets in the sides or slopes of hills and valleys, are all dependent upon the rainfall for their genesis; but it is not always that Nature presents her resources in such a way that they can be utilized without the assistance of the scientist and the work of development of the civil engineer.

I have before treated this subject somewhat in detail in a paper upon Rainfall and Wells read before your Society in the late Engineering Section.

With regard to surface springs, their appearance, as a rule, is due to the relieving of water-logged strata, or to the overflow of conserved water in basins and chasms through natural channels, or they are thrown out by the existence of an impervious underlying strata or by faults or upthrows which arrest the passage of the water through the interstices of the different formations to its natural outlet. Such are found in the Pennant Grit, New Red Sandstone, Chalk, etc., and the form in which these springs present themselves varies much. For instance, at a spring at Rickford, on the north slope of the Mendips, which has its gathering ground doubtless in the direction of Burrington and Blackdown, the spring issues direct out of the face of the Mountain Limestone in close connection with the Dolomitic, and is very quickly affected by the rainfall upon its area, gushing out in large quantities = 8–10 million gallons per diem after heavy rainfalls, and receding as quickly and almost ceasing to flow in dry-weather periods. Mountain Limestone, as is well known, abounds in vertical jointings, which carry the water down quickly into the underground basins and cavern-like formations met with in that formation. Again, in chalk and sandstone districts, especially in the Keuper and New Red Sandstone, the water wells up in numerous small springs, and very often these springs have to be collected together to bring them into a focus for delivery and use. Such springs, which I have had to deal with, occur in the north-east flanks of the Mendips at Sherborne, where a spring is collected issuing from the New Red Sandstone and Dolomitic conglomerate = $1\frac{1}{2}$ million gallons per diem. Again at Backwell and Chelvey, where they ooze out in swampy and marshy levels or flats in accordance with the amount of drainage area they command, they are equal to six or seven million gallons per diem; and in the Nailsea Basin, lying to the north of Backwell, we have a good deal of water stored in the Pennant Grit overlying the coal measures, which is a source of difficulty in winning the coal in that basin.

The flow of surface springs is very often affected by barometrical pressure; for instance, we often hear it said in the country that when the wind is in a certain quarter the springs are affected and flow less freely for a time, and *vice versâ.* When this comes to be inquired into, the cause and effect is soon found. When the wind is in the south-west, the barometer is low; it may fall, for example, from 30·25–29·25, *i.e.* 1 inch, which means the loss of about ½ lb. pressure on the square inch; or if a more sudden fall to 28·25 is reached, there is a loss of 1 lb. to the square inch, and less pressure is therefore suddenly exerted upon the outflow of the spring. The force or energy producing the spring, be it hydrostatic or atmospheric, is indirectly affected by this loss of pressure on the outflow, inasmuch as the change of atmospheric pressure is not conveyed through the interstices of the earth and strata down to the source or genesis of the spring in anything like the same ratio that it affects the outlet of the spring, and *vice versâ* with a rise in the barometer the reverse takes place. In coal mines and other shafts, where it is a matter of equilibrium, apart from latent or accumulated energy in the gases themselves, differences of atmospheric pressure act in a similar way in releasing or holding back gases, since barometrical changes are there more quickly felt than at greater depths in the bowels of the earth.

The behaviour of springs both in the surface and in wells varies very much in their yield and mode of issue, and also varies chemically, being either hard or soft, according to the strata through which they pass, and yielding constituents which often in themselves are useful for particular purposes. For instance, we have waters which contain a good deal of carbonic acid gas and others which absorb more freely carbonic acid gas (useful to mineral water manufacturers), and, again, the waters which have a large proportion of sulphates are much sought after by brewers. This is one of the secrets of the good quality and class of ales we get from the Burton Brewery, where the water is derived from the sandstone wells, which contain a large proportion of sulphates.

To enable man to get the full benefit from springs resource is very often had to sinking and boring, as thereby the springs are opened out and expanded so as to meet the wants of the adjacent masses of civilization, and the cost of going further afield for river and surface spring supplies may be obviated. There may be also the further benefit of obtaining water free from sewage contamination and pathological organisms, for which the ever-watchful analytical chemists are constantly on the look-out.

These wells and borings through the different strata are productive of a good deal of useful information, and it is then that we find what a network of underground movement in water and hidden energy is going on of which we should otherwise be perfectly ignorant. For instance, in connection with the huge spring met with in the sinking of the Sudbrook shaft for the Severn Tunnel, we have an instance of an immense underground river or body of water being suddenly released by being intersected in its course most probably to the Severn. Having had occasion to examine this spring and the adjacent watershed, in conjunction with other engineers, there is no doubt in my mind that this water had its gathering ground far away to the north-west (in the Old Red Sandstone and Mountain Limestone) in the Wentwood Forest and drawing through swallet-holes in the Cas-Troggy Brook (which I have myself observed), and which formed one source of the numerous feeders to the underground fissures contributing to the huge volume of water intersected. Again, at Cheddar, on the south-west slope of the Mendips, in the Cheddar Valley we have another instance of a natural outlet of a swallet fed in underground channels situate in the Carboniferous Limestone having its contributing area extending over a considerable watershed, most probably in an east direction from the table land in the neighbourhood of Charter House and Priddy. And, again, on the north slope of the Mendips, at Banwell, we have another instance of one of these large outlets of the drainage area of the Mendips, probably from a south-east direction. This outlet, in the middle of the Banwell pond, I have myself gauged in 1885, and the uprush of water through an inverted cone, which is very discoloured after heavy rains and throwing up a constant collection of sand and grit and shell or limnæa, is equal to a quantity of 5–10 million gallons per day, according to rainfall.

There are further illustrations of springs in the neighbourhood with which we are more familiar, viz., in the spring issuing on the south side of the Avon just below the Suspension Bridge. This has its gathering ground doubtless in the south-west area of the Carboniferous Limestone around Failand in the outcrop of Mountain Limestone superposing the Old Red Sandstone formation. This is an intermittent spring, which flows about half a million gallons per diem in wet seasons, sinking to nil in the summer, as in 1887–1893, when it stopped entirely, and is not perennial like the Sherborne spring before mentioned, which I have never known lower than one million gallons per day. Again we have the Hotwells spring and Buckingham and Richmond springs, over the site of which the original Waterworks Company sunk wells to supply parts of Clifton; this is a case where the evidence of water-bearing strata is augmented by sinking deeper for the purpose of increasing or opening out the yield of underground water.

With reference to sinking and boring wells, I have before, in connection with our local Engineering Society, treated upon wells sunk in the New Red Sandstone; but I thought it would be interesting to members to see some

18 in. cores in connection with a bore-hole I put down (for my Company) at Chelvey, on the Keuper Marls, New Red Sandstone, and Dolomitic conglomerate, samples of which I have here. In this case the hole was commenced 160 feet below surface (the surface being 50 feet below sea level), or say 100 feet below sea level where the boring was commenced, and, as the section shows, to a depth of 400 feet. The larger bulk of water was met with in the Sandstone, about 200 feet from surface, and other small quantities at depths of 230–290 feet. The passage from the Keuper Sandstone to the Dolomitic is very clearly marked, and the Dolomitic proved to be about 30 feet thick when the blue duns of the coal measures were reached, which shows that we were near the outcrop of the Nailsea Coal Basin. Here the boring was stopped, and I may remark that the additional yield due to this hole was afterwards proved by pumping to be about a million gallons.

It may be interesting to the Society to explain here the mode of boring these holes. It is done with a diamond crown (that is black diamonds set in a steel coronet), which is attached to screwed tubes and rotated by engine power and suitable gear from the surface by connecting rods and tubes. A core like the sample is cut out and withdrawn as required.

The means of withdrawing and holding the core is also interesting; the core is pressed up into a tube about 15 or 20 feet in length. About two-thirds up its length it has a diaphragm, which, as the rotation goes on, allows the debris to pass the sides of the core by an annular space and become deposited in the top shelf of the tube. When the core is of such a length that it requires drawing, or should it break off, it is secured by a split ring tightening in an inverted cone, which, by the action of lifting the tubes, is tightly wedged around the core, and in the case of the broken core there is an arrangement of pawls which, when the lifting of the tube is commenced, digs into the walls of the core and effectually prevents it from slipping.

Coming nearer home, I might perhaps describe the proving of some springs known as the Boiling Wells, which would interest the members generally, as I believe it is often a resort for naturalists in their early work for the purpose of selecting different aquatic plants and specimens, which are only to be found where there is a perennial water supply. These so-called "Boiling Springs" yield from half to three-quarter millions of good pure water per diem, which comes from a depth of 18–21 feet below surface, or at a level of 50 feet above O.D., or mean sea level, and issue through the marly coverings to the sands and clays of the Keuper Beds (the upper division of the Trias or New Red Sandstone ranging north and south).

Speaking geologically, the spring, I think, issues from fissures occasioned by a faulted and denuded area in the marls and sandy series; that is to say, on the north-west side of the valley by Ashley Hill we get the Lower Lias at an elevation, and on the south-east side we get the Keuper Marls at a similar elevation, showing that the lias has become denuded, or is absent or disappeared, due to the upthrow of the Keuper Marls and New Red Sandstone, denoting that the eastern side of the valley is considerably higher than it should geologically be, causing the fault which produced the springs. Doubtless the spring overlies the Dolomitic conglomerate, which holds up or retains the supply to the springs fed from its watershed through broken or faulted ground to the surface as it exists.

The way in which I dealt with these springs to prove them was to put down three 10 in. bore-holes at intervals over the area occupied by the springs, carrying down one hole for the purpose of ascertaining if any more water existed to a depth of 100 feet, and inserting driven wrought-iron tubes, perforated, to allow the water to enter. These I coupled together by a horizontal tube, which conveyed the water to the pumps direct without any outside contamination, and I may mention that to get the full benefits of the issuing water I arranged a vacuum chamber to be fixed to the range of tubes, so that when the tapped spring rose up with its natural head into the vacuum chamber it would displace the air through a valve provided for the purpose, and when this was finally closed the spring would then be sucked up, or have its natural statical head rising in a vacuum instead of against atmospheric pressure, which increases its yield, due to the benefit gained by the loss of atmospheric pressure.

I trust the few remarks I have made have been of interest to the members, and that my explanations and descriptions have conveyed some idea of the engineering work in connection with the collection and treatment of springs.

On the Classification of the Tilopteridaceæ.

By GEORGE BREBNER,

Lecturer in Botany, University College, Bristol.

THE small, though interesting, group of the Brown Sea-weeds, known as the Tilopteridaceæ, consisted until recently of the three well-known genera *Tilopteris*, *Haplospora*, and *Scaphospora*, but in 1895 Kuckuck [1] suggested that *Haplospora Vidovichii* (Kütz.) Bornet should be renamed *Heterospora Vidovichii* on account of his discovery of uni-locular zoosporangia in that species. Kuckuck, however, did not suggest its removal from the Tilopteridaceæ, hence a fourth genus, *Heterospora*, would have to be added to that family, at any rate *pro tem.*

The type species, *Tilopteris Mertensii* Kütz., was first found on the beach at Yarmouth in 1799 and named *Conferva Mertensii* by Turner.[2] It was subsequently rechristened *Ectocarpus Mertensii* by C. Agardh,[3] because it very

[1] P. Kuckuck, Ueber Schwärmsporenbildung bei den Tilopterideen und über *Choristocarpus tenellus* (Kütz.) Zan. (Jahrbücher für wissensch. Botanik, vol. xxviii., No. 2).

[2] For fig. see English Botany, Pl. 999.

[3] C. A. Agardh, *Species algarum*, ii., p. 47.

closely resembles the genus *Ectocarpus* in vegetative structure. Kützing,[1] later, taking certain anatomical details into consideration, renamed the plant *Tilopteris Mertensii*, leaving it, however, among the Ectocarpaceæ. Thuret[2] next removed it from that family on account of its possessing large immobile spores, and created the order Tilopteridaceæ ("Tilopterideæ") to receive it.

Kjellman,[3] in 1871, added the new genus *Haplospora*, and later, in 1875,[4] the genus *Scaphospora.*

For an interesting historical account the reader is referred to Reinke's[5] important paper on the family, the above being the merest outline, and only in so far as it affects the classification.

Although *Tilopteris Mertensii* Kütz. was first found, and recognised as a distinct species, in Britain, the types of Kjellman's two additional genera were overlooked in this country until recently, when first, in 1893,[6] *Haplospora globosa* Kjellm. was found at Millport, Cumbræ, N.B., and then, in 1894,[7] at the same place, the very much rarer *Scaphospora speciosa* Kjellm. An exceedingly small quantity of the latter was obtained, only sufficient to yield one herbarium specimen and a few microscope slides In 1895

[1] Kützing, *Species algarum*, p. 462.

[2] Thuret, Recherches sur la fécondation des Fucacées et les anthéridies des algues. Seconde partie. (Ann. d. sciences nat., 4 Ser., Pl. III., 1855.)

[3] F. R. Kjellman, Bidrag till Kännedomen om Skandinaviens *Ectocarpeer* och *Tilopterider*. Stockholm, 1872, p. 3.

[4] Ueber die Algenvegetation des Murmanschen Meeres. Upsala, 1877, p. 29.

[5] J. Reinke, Ein Fragment aus der Naturgeschichte der Tilopterideen (Botan. Zeitung, 1889, No. 7–9).

[6] Found by the writer, and recorded by Edw. Batters in Grevillea, vol. xxi., p. 97.

[7] *Ibid.*, vol. xxii., p. 116.

another very small plant of *Scaphospora speciosa* was found. In 1896, although again carefully hunted for, no specimens could be obtained, although *Haplospora* was present in quantity, as on all the previous occasions.

A fifth visit to the locality was made in April of the present year (1897), with two objects in view: firstly, to conduct, if possible, fertilisation experiments with *Tilopteris Mertensii* Kütz., which plant occurs in great abundance on the same ground as *Haplospora globosa*, and secondly to try to get further information as to the relation of *Haplospora* to *Scaphospora*. The latter object, but not the former, was accomplished.

In vegetative structure *Haplospora globosa* is absolutely identical, histologically, with *Scaphospora speciosa*, and Reinke came to the conclusion that these plants were in all probability not only generically, but also specifically, identical (Figs. 1, 2, 3, 4, 5, 6). Kjellman had found antheridia of the Tilopteridean type (Figs. 3 and 7, *an.*) on a specimen of *Haplospora* which he described, but did not figure. Subsequently he doubted the accuracy of his observation, which Reinke[1] likewise was unable to confirm, although he examined hundreds of specimens of *Haplospora*. In the course of the present investigation, extending over five years, hundreds, perhaps thousands, of specimens of *H. globosa* were examined, but it was not until the present year that this question received its final solution through the finding of a specimen bearing well developed, though not mature, *sporangia*,[2] *oogonia*, and *antheridia*, all perfectly unmistakable and characteristic (Figs. 7 and 8, *sp.*,

[1] Cf. Reinke, l.c. *Sep. Abdr.*, p. 2.

[2] The term "sporangium" will be used throughout this paper for the non-sexual reproductive organ of *Haplospora*, which contains a tetra-nucleate monospore.

oog., *an.*). The plant in question was about two inches long, and as far as one could judge by naked-eye-characters, indistinguishable from an ordinary small specimen of *Haplospora*. Oogonia and sporangia were present in abundance, but the antheridia were considerably less numerous. Further, where the antheridia occur most abundantly the sporangia are relatively less numerous than elsewhere, and likewise less mature, at the most having two nuclei; whilst on other parts they were found in the tetra-nucleate condition (Fig. 8, the lower of the two sporangia marked sp.).

This specimen might, therefore, with almost equal propriety, be looked upon as a sexual plant, bearing, exceptionally, non-sexual sporangia or *vice versâ*. The vegetative part is histologically indistinguishable from that of *Scaphospora speciosa*, or *Haplospora globosa*, and, since in its reproductive organs it unites the characters of these two supposed distinct species, there is now no room to doubt that *Haplospora globosa* Kjellm., and *Scaphospora speciosa* Kjellm. are not only generically, but specifically identical, these names having been applied to different conditions of the same plant. The credit of the first recognition of this is due to Reinke as already indicated.

Reinke's supposition seemed so reasonable to the writer that drawings of young plants of *Scaphospora* and *Haplospora* were made (Figs. 1 and 2) and exhibited at a meeting of the Linnean Society, 21st June, 1894, and this view strongly advocated, although at that time no actual confirmation had been obtained. The object of the figures was to show that there was no essential difference of habit in the two plants, the apparent difference in Kjellman's description being due simply to the modifying effect of the mature reproductive bodies on the external morphology. Such modification is not uncommon, especially among algæ, and it is not desirable to rely to too great an extent upon habit as a diagnostic character unless accompanied by demonstrable differences in histological structure.

From what has been said above, it is obvious that *Haplospora* and *Scaphospora* can no longer be regarded as separate and independent genera, and the question arises which of the two, if either, is to be retained. This should present no difficulty, since the genus *Haplospora* was established by Kjellman[1] five years before *Scaphospora*,[2] and therefore, by the accepted laws of nomenclature, must be retained on the mere ground of priority of description. Kjellman had already described *Scaphospora speciosa* under the name *Capsicarpella speciosa* at the time he made the new genus *Haplospora*, but placed it among the *Ectocarpaceæ*. He subsequently, however, rejected the generic name *Capsicarpella* (Bory) Kjellm. in favour of *Scaphospora*, at the same time placing the alga among the Tilopteridaceæ, and this latter genus has since been generally accepted. Reinke[3] suggests that both *Haplospora* and *Scaphospora* should be merged in *Tilopteris*, but it seems hardly desirable to adopt this course, for *Haplospora* has long been established, and almost universally accepted as valid by algolgists of all shades of opinion. Moreover, there are valid reasons for regarding it as an independent genus. The real difference between the genera *Tilopteris* and *Haplospora* seems to lie in the fact that in the former the sporangia and (presumed) oogonia are similar in form, and occupy a similar position in the frond, while in *Haplospora* (Kjellm.) *limit. mutat.*, the oogonia and sporangia are dissimilar in form, and normally occupy different positions in the frond. One of Reinke's reasons for considering that *Scaphospora* Kjellm. and *Haplospora*

[1] l.c. [2] l.c., p. 29. [3] l.c. *Sep. Abdr.*, p. 17.

Kjellm. were identical was that he found what he considered non-sexual sporangia developed in a manner homologous with that of the oogonia.[1] From what is now known it is quite possible that these are actually immature oogonia. The condition shown at Fig. 10 *a β* (l.c.) might be due to the attack of a Rhizopodium, such a knee-like appearance being often due to the parasite. It may, indeed, later on, be recognised as such, although in the early stage of the attack it is hardly distinguishable from a developing sporangium. Whether or not this be the correct interpretation, sporangia do occasionally occur in an intercalary position in *H. globosa*. It was partly on account of this occurrence of intercalary sporangia in *Haplospora* that Reinke proposed to unite *Scaphospora speciosa* and *Haplospora globosa* under the genus *Tilopteris*, calling the plant *Tilopteris globosa*. In view of the instability which is rather characteristic of marine algæ, this variation is of doubtful systematic significance. Classification should depend on normal structure, although abnormalities may be useful in giving clues to correct interpretation.

Subsequently to the finding of the plant with all three kinds of reproductive organs, a specimen of *H. globosa* was secured bearing, besides the usual sporangia, a few undoubted *oogonia*, but no antheridia.

The modified genus *Haplospora* may therefore be diagnosed as follows:—

Haplospora (Kjellm.) *limit. mutat.* Fronds filiform, monosiphonous above, more or less polysiphonous below, branches issuing irregularly from all sides of the main stem. Chromatophores small, roundish, many in each cell. Growth, trichothallic. Asexual reproduction by motionless tetranucleate spores formed singly in terminal stalked, sessile,

[1] Cf. l.c., *Sep. Abdr.* p. 16, and Figs. 10 *b δ* and *c η*, Pl. II.

or rarely intercalary sporangia. Sexual reproduction oogamous (?), oogonia spherical, slightly flattened below, partly immersed in the frond. Antheridia intercalary, tubular, formed by the transformation of one or more cells in the continuity of the filament. Spermatozoid mother-cells arranged in longitudinal and transverse rows, forming the wall of the antheridial tube. Spermatozoids, bi-ciliated, with two chromatophores. Individuals either asexual, hermaphrodite, or sporo-hermaphrodite.

Haplospora globosa (Kjellman) *limit. mutat.* Filaments from an inch to twelve inches long, rich brown, turning olive green on drying, tufted, densely decompoundly branched, branches and branchlets opposite, alternate, subsecund or scattered. Attachment by means of rhizoids. Cells of the main filaments 60–80μ wide, as long as or slightly longer than broad, those of the ultimate branchlets about 30μ, and much broader than long in the lower part, gradually passing into long narrow cells, which are almost colourless. Chromatophores small, oval, numerous. Asexual sporangia globose, 60–100μ (85–114μ. Kjellm.) in diameter (usually 60–70μ in Brit. specimens), usually borne on one or many-celled stalks, more rarely sessile or intercalary. Oogonia spherical, slightly flattened at the base, partly immersed in the frond, 50–80μ (90–118μ. Kjellm.) in diameter. Antheridia 30–150μ long, 28–50μ wide. Distribution, Scandinavia, Baltic, N. America, Clyde, N.B.

The question now to be considered is, how does this affect the classification of the Tilopteridaceæ? It seems to justify the exclusion from the group of all plants devoid of the characteristic tubular antheridia, the possession of which is perhaps the most characteristic feature now that *H. globosa* and *Sc. speciosa* are known to be one species. *Scaphospora arctica* Kjellm. was considered by Reinke to be, at most, a variety of *Sc. speciosa*, and this view has received considerable support by the fresh information gained. The same also applies probably to *Scaphospora* (?) *Kingii*, Farlow.[1]

With regard to *Haplospora Vidovichii* (Kütz.) Bornet,[2] or *Heterospora Vidovichii* (Bornet) Kuck., it seems undesirable to leave it in the Tilopteridaceæ, because the interesting discoveries recently made by Kuckuck tend to show that it differs in several essential respects from the Tilopteridaceæ. To sum up the differences, *Heterospora* is not polysiphonous below, as are always *Haplospora* and *Tilopteris*; it has, so far as is known, no pluri-locular tubular antheridia; the monospores are uni-nucleate, whereas in *Tilopteris* and *Haplospora* the spores contain more than one nucleus; and it has uni-locular zoosporangia, which are entirely unknown in *Tilopteris* and *Haplospora*. All these features, which are characteristic of *Heterospora Vidovichii*, tend to separate this plant from the Tilopteridaceæ, and several of them bring it nearer to the Ectocarpaceæ, among which it might be provisionally placed in a sub-order Heterosporeæ, or a new order for its reception might be created, as it differs from all the true Ectocarpaceæ in having monospores.

Further, with regard to *Choristocarpus tenellus* (Kütz.) Zan., Kuckuck[3] is of opinion that it should not be included in the Tilopteridaceæ as suggested by Zanardini. The facts that this plant has apical growth and that the apparent monospores are gemmæ, in conjunction with the data given above, fully justify this attitude.

[1] W. G. Farlow, On New England Algæ (*Bulletin of the Torrey Botanical Club*, May, 1882).

[2] Bornet, *Notes sur quelques Ectocarpus*, 1891 (*Bullet. de la Soc. bot. de France*, No. 6). [3] l.c., p. 313.

The well-marked oogamous (?) reproduction in the Tilopteridaceæ, together with the non-motile tetra-nucleate monospores, at any rate in *H. globosa*, and the polysiphonous structure of the lower part of the frond, make this family rather difficult to place phylogenetically. The vegetative structure separates these algæ very far from the Dictyotaceæ, with which nevertheless the reproductive organs show certain analogies. Again, the structure of the lower part of the frond shows great similarity to that of *Sphacelaria*, but in the latter, growth is by a well-marked apical cell, not trichothallic as in the Tilopteridaceæ. Apart from the longitudinal septa, the frond is very Ectocarpus-like, and as there seems to be a tendency towards oogamous reproduction in some species of that genus (*i.e.* in the differentiation of the planogametes [1]), it might not be amiss to place this group near the Ectocarpaceæ. On the whole, however, it seems better to place the Tilopteridaceæ provisionally in the *oogamous* division of the Phæophyceæ, as is done in the classification adopted by Prof. Vines in his student's textbook.

With regard to the Tilopteridaceæ themselves they may now be classified as follows:—

Family, Tilopteridaceæ.

Genera:—

Tilopterîs Kütz.

Haplospora (Kjellm.) *limit. mutat.*

Species:—

Tilopteris Mertensii Kütz.

Haplospora globosa (Kjellm.) *limit. mutat.*

(,, *arctica* Kjellm.) ?

(,, *Kingii* Farlow) ?

[1] Bornet, l.c. p. 1, *et seq.* Sauvageau, *Observations relatives à la sexualité des Phéosporées* (*Journal de botanique*, vol. x., Nos. 22 and 23, 1896; vol. xi., Nos. 1, 2, and 4, 1897).

The group is thus a very limited one, and may be all that survives of a large oogamous group with simple filamentous type of thallus, although more probably it is a recently developed one arising by reduction of megaplanogametes to an ovum, and zoospores to a tetra-nucleate monospore.

In Tilopteris the oogonia are ordinarily indistinguishable from the sporangia, and now it is no longer safe to assume that, because an individual bears antheridia, the other organs are all oogonia, although in most cases it may be inferred that they are so. In *Haplospora globosa* (Kjellm.) *limit. mutat.* the following conditions have been found with regard to the reproductive organs :—

1. Sporo-hermaphrodite.
2. Hermaphrodite.
3. Sporo-antheridic. (Kjellm.)
4. Sporo-oogonous.
5. Non-sexual.

The second and fifth are the typical states, all the others being exceedingly rare. It is extremely likely that all these conditions occur more or less commonly in *Tilopteris.* Reinke found two, four, or more nuclei in the sporangia of *Tilopteris*, and such are probably non-sexual, but the multinucleate condition may have been due to the commencement of germination of the spore in situ, which is not uncommon in *Tilopteris Mertensii.* Certain it is, however, that from antheridia-bearing specimens, uni-nucleate bodies are discharged which do not possess a recognisable wall; hence there can be little doubt that they are ova.

The process of fertilisation and the subsequent early stages in germination have yet to be observed, but when that is done the life-history of these algæ will be practically complete, for already most of the germination stages have been observed both in *Tilopteris* and *Haplospora* up to the recognisable young plant. This is only the case, however, with regard to the monospores of *Haplospora*, and probably the earliest stages in germination of the fertilised ovum,[1] but it is doubtful whether the germination stages observed in *Tilopteris* are from fertilised ova or non-sexual spores.

There is no question of fertilisation through a cell-membrane, or wall, as supposed by some, since in *Haplospora limit. mutat.* it is only the non-sexual spores that leave the sporangium invested by a wall, the ova being uni-nucleate naked bodies.[2] It is presumably the same in Tilopteris, at any rate naked uni-nucleate bodies, presumptive ova, are discharged from antheridic plants, as already mentioned.

The writer hopes next year to carry on these investigations with a view to clearing up the remaining obscure points, but at the same time trusts that others will likewise take the matter up, especially those who have the opportunity of getting the sexual plants of *Haplospora globosa limit. mutat.* in fair abundance, which so far has been impossible in this country.

The work at Millport on this group was carried out chiefly by the aid of a series of Government Grants, for which the writer wishes to express his best thanks to the Grant Committee of the Royal Society. He wishes likewise to express his great indebtedness to Dr. John Murray and those in charge of the Marine Station, Millport, for their friendly permission to make use of the "Ark" and its resources, for without such assistance these researches could not well have been undertaken.

Hearty thanks are also due to Mr. Edward Batters for assistance in identifying species, and for placing his wide knowledge of the literature of the subject at the writer's disposal, to say nothing of kind encouragement and advice.

[1] Reinke, l.c. *Sep. Abdr.*, p. 12. [2] *Ibid.*

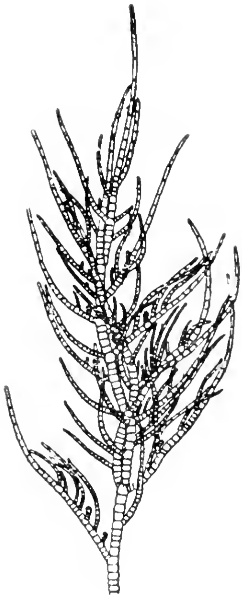


Fig. 1

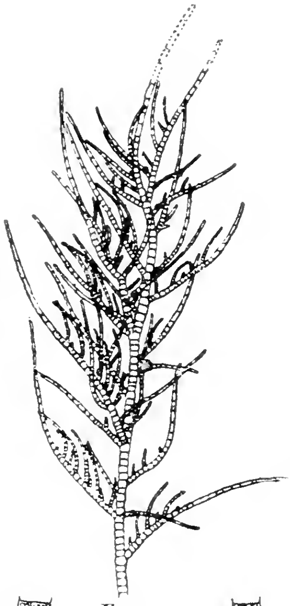


Fig 2

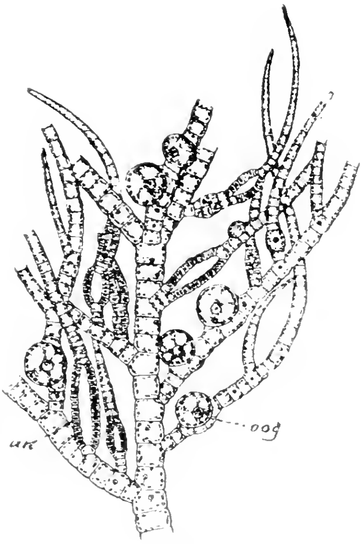


Fig. 3

Fig. 5

Fig. 6

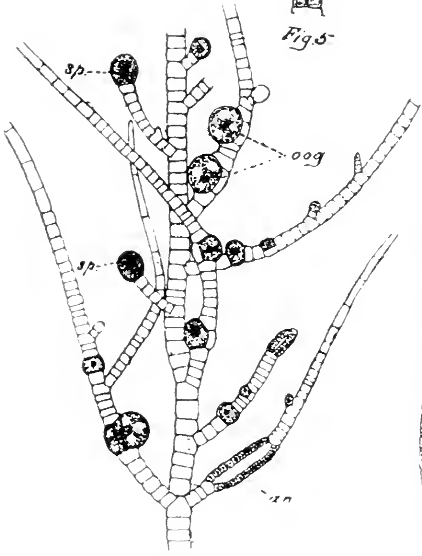


Fig 7

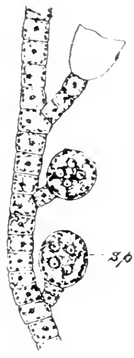


Fig 4

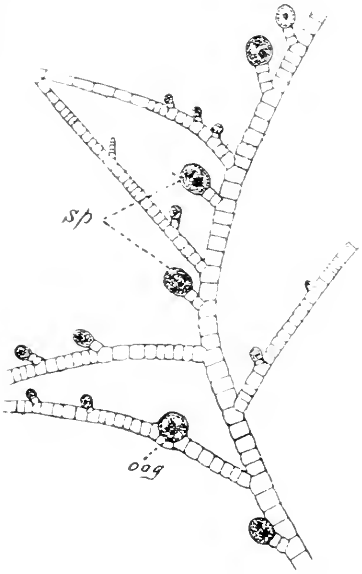


Fig. 8

G. Brebner del.

EXPLANATION OF THE FIGURES IN PLATE.

FIG. 1. Part of a young plant of *Haplospora globosa*, Kjellm. ×25.

" 2. Ditto of *Scaphospora speciosa*, Kjellm. ×25.

" 3. *Sc. speciosa*, Kjell. The oogonia *oog.* and antheridia *an.* are almost mature. ×100.

" 4. *H. globosa*, Kjellm. Portion of a branchlet with two adult tetra-nucleate sporangia, and a third which has already discharged its contents. ×100.

" 5. Portion of the lower part of a young specimen of *Sc. speciosa*, Kjell., showing first longitudinal division of thallus cells. ×100.

" 6. Ditto of *H. globosa*, Kjell. ×100.

" 7. *Haplospora globosa*, limit. mutat., showing oogonia *oog.*, antheridia *an.*, and sporangia *sp.* all borne on the same plant. ×75.

" 8. Another part of the same specimen as that of Fig. 7. On this there is only one oogonium, but many sporangia, one of the latter showing the characteristic four nuclei. ×75.

Note.—The antheridia, as also the oogonia and sporangia, are figured in optical section.

The Geological Structure of the Upper Portion of Dundry Hill.

By S. S. BUCKMAN, F.G.S., and E. WILSON, F.G.S.

I. Introduction.

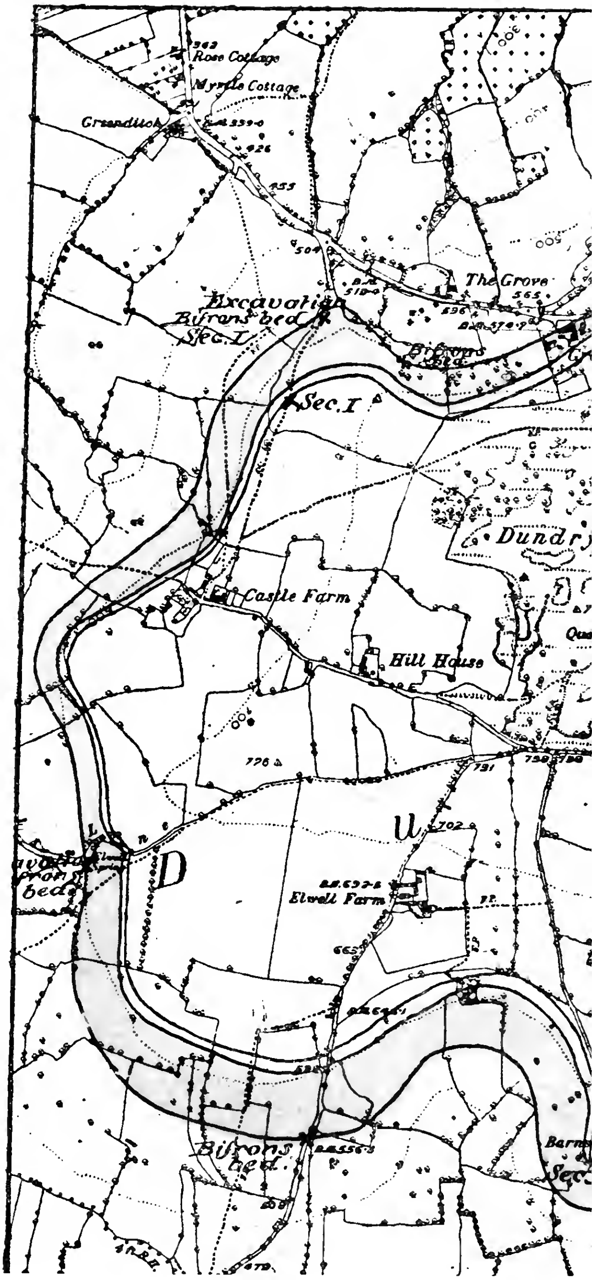
THE strata which we have investigated form the upper portion—about the upper 100 feet—of that isolated, flat-topped eminence known as Dundry Hill. They comprise deposits which would usually be known as Marlstone, Upper Lias, Supra-liassic sands, and Inferior Oolite. Owing apparently to a similarity in lithic structure between the Marlstone-rock and a certain well-known bed of the Inferior Oolite, the whole of the above-mentioned deposits have been mapped by the officers of the Geological Survey as Inferior Oolite (*g* 5) around nearly the whole of Dundry Hill.

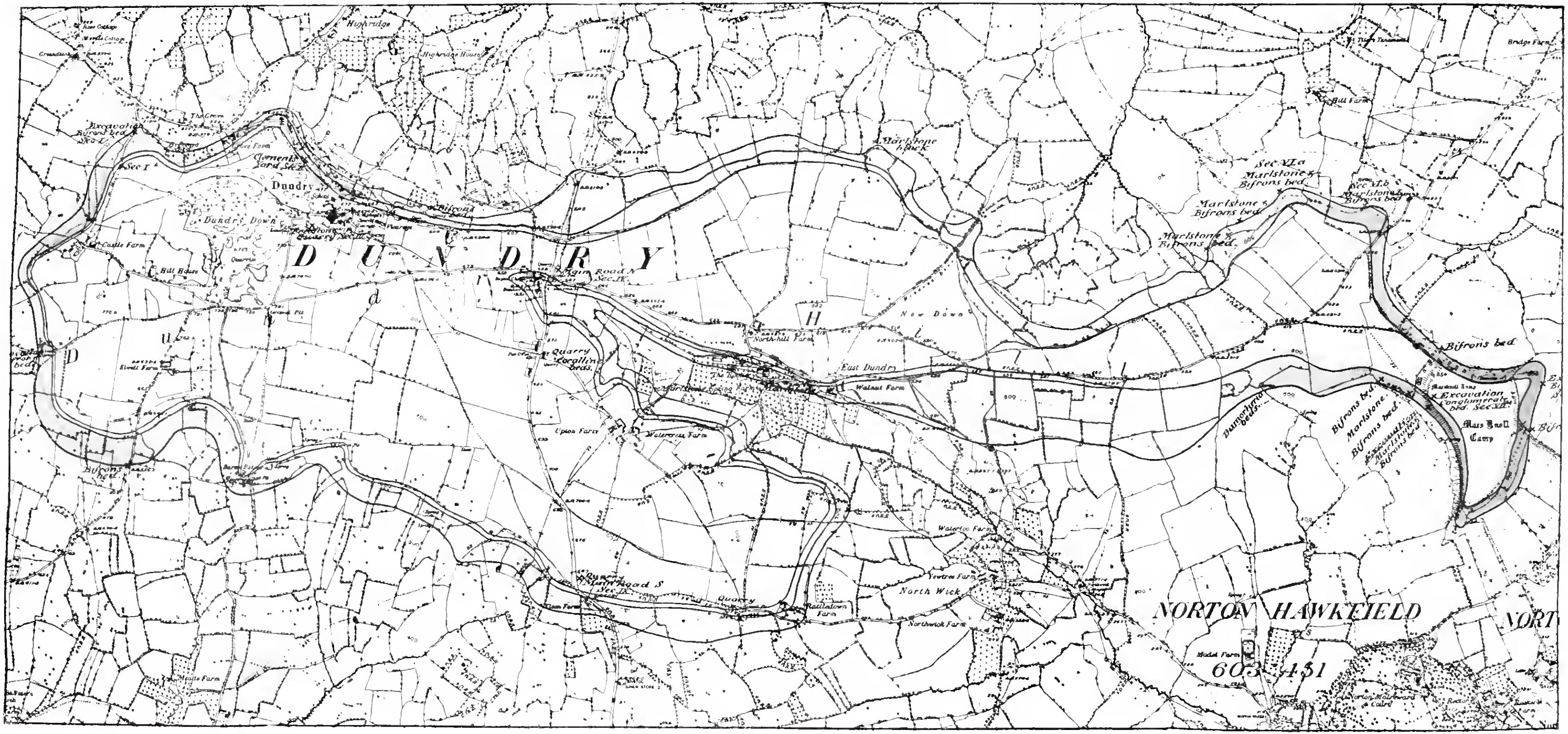
II. Historical Retrospect.

We would notice certain publications which have dealt with the strata of this hill in order to show what has been accomplished.

Conybeare and Phillips[1] noticed Dundry Hill, and referred to the ironshot nature of the stone; while De la

[1] 'Geology of England and Wales,' pt. i. (1822), p. 236.


Rose Cottage
Myrtle Cottage
Greenditch
The Grove
Excavation
Bifrons bed
Sec. I
Sec. I
Bifrons bed
Dundry
Castle Farm
Hill House
D
U
Elwell Farm
Bifrons bed


DUNDRY
Dundry
Dundry Down
Highridge
Highridge House
The Grove
Excavation Bifrons bed Sec I.
Sec I
Clements Yard Sec II
Castle Farm
Hill House
Quarry Coralline beds.
Main Road N Sec IV
New Down
Northhill Farm
East Dundry
Walnut Farm
Marlstone Mark
Sec VI a Marlstone & Bifrons bed
Marlstone & Bifrons bed
Marlstone & Bifrons bed
Sec VI b Marlstone & Bifrons bed
Hill Farm
Bridge Farm
Bifrons bed
Excavation Conglomerate bed. Sec VII
Maes Knoll Camp
Dumortieria beds.
Bifrons bed
Marlstone
Bifrons bed
Excavation Marlstone Bifrons bed
Upton Farm
Watercress Farm
Bifrons bed
Quarry Main Road S Sec IX
Quarry
Rattledown Farm
Northwick Farm
North Wick
Yewtree Farm
Waterloo Farm
NORTON HAWKFIELD
NORT
Model Farm
603·451

Beche[1] mentioned it, but only in a general way, as a locality for Inferior Oolite. H. E. Strickland[2] correlated the Oolite of Dundry with the pisolite of Cheltenham, the Cephalopod-bed at Haresfield Hill, and the Oolite of Bridport.

In 1857 Lycett[3] shortly noticed Dundry and compared its beds with those of the Cotteswolds. He correlated "the ragstone" (evidently the coralline beds) with his *spinosa*-stage; the building stone with the *fimbria*-stage, and the Ironshot oolite with the Cheltenham pisolite.

In 1859 Wright[4] gave an account of the Inferior Oolite, and in his paper published certain "Notes on Dundry Hill, by R. Etheridge."

The sequence of the strata was given in the following terms:—

	Feet.
"7. Building-stone or Freestone beds . . .	12
6. Fine-grained oolite	4
5. Ragstones (shells)	8
3 & 4. Rubbly Limestones (shells)	12
2. Ammonite bed . . . . }	5
1. Ironshot shelly bed . . . . }	
a. Upper Lias Sands	2
b. Lower Lias	500"

In regard to this section, we notice the following points:—

1. That no Middle Lias is mentioned; and on this subject Mr. Etheridge is very emphatic, saying (p. 22), "In this fine development there are *no traces whatever of the Middle Lias or Marlstone* as exhibited in the Bath district, and in the Cotteswold Range generally."

[1] 'Report on the Geology of Cornwall, Devon, and West Somerset,' London, 1839, p. 234.

[2] *Quart. Journ. Geol. Soc.*, vol. vi. (1850), p. 249.

[3] 'The Cotteswold Hills,' London and Stroud (1857), p. 72.

[4] 'On the Sub-divisions of the Inferior Oolite in the South of England, etc.;' *Quart. Journ. Geol. Soc.*, vol. xvi. (1860), pp. 5–48.

2. That the Upper Lias sands are stated to be 2 feet in thickness; "they pass downwards into the clays and shales of the Lias beneath." They are said to underlie a shelly bed which, together with the Ammonite-bed, is 5 feet in thickness. From the list of fossils given it would seem that the "Ammonite-bed" is what we shall call presently '*the* Ironshot Oolite.' As to the sands, we find sandy limestone and marl at about the position indicated; and we think it probable that these are the strata which Mr. Etheridge referred to "Upper Lias Sands." However, they yield *Terebratula Eudesi*, Oppel, and *T. cortonensis*, S. Buckman, indicative of a much later date (*see Table II., facing p.* 212).

In regard to the other beds we would make the following remarks—

"No. 5.—*The Ragstones of Dundry forming the zone of* Ammonites Parkinsoni." There is evidently some confusion here. The description and the fossils given answer partly to what we call 'the Coralline beds,' and partly to our '*Terebratula Eudesi*-beds.'

"Nos. 6 and 7. The Building-stone." This is said to be the highest set of beds at Dundry; but we find them to be covered by several feet of Coralline Limestone.

In 1875 E. B. Tawney[1] noticed Dundry and Mr. Etheridge's communication thereon, observing that the succession of beds as given by the author cited is open to some doubt. On his own part Tawney remarks that "*A. Murchisonæ*, *Sowerbyi*, and *Humphriesianus* seem to occur together."

James Buckman[2] considered the beds at Dundry and at Bradford [Abbas] to be on the same horizon, and that they

[1] 'Bristol and its Environs,'—published under sanction of local Executive Committee of Brit. Assoc. (1875).—'Inferior Oolite,' by E. B. Tawney, p. 378. [2] *Quart. Journ. Geol. Soc.*, vol. xxxiii. (1877), p. 3.

had not the slightest connection with the Cephalopod-bed of Gloucestershire, thus correcting some earlier authors.

W. W. Stoddart[1] compared Dundry Hill to an island, presumably in the Jurassic sea! He gives a diagrammatic section of the strata of the whole hill in the forefront of his paper. He notes that Middle Lias is present; but the evidence quoted entirely destroys the value of the assertion. "A bluish marly limestone about a foot in thickness and corresponding to the marlstone. . . . so full of the shells of *Am. thouarsensis*, *A. radians*, and *A. aalensis*, that the presence of the Middle Lias is fully justified" (p. 284). There is obviously a mistake here; these are ammonites of what Oppel called the '*Lias-oolith Grenzschichten*'—the Cotteswold Cephalopod-bed equivalent,—and they have never been found in Middle Lias.

In general features the section given by Stoddart corresponds with that by Mr. Etheridge; but our researches do not confirm the sequence which he describes.

In 1878 Mr. J. F. Walker[2] compared the brachiopoda of Dundry with those of Dorset and the Cheltenham district, pointing out that certain species were common to Dundry and Dorset, and were not found in the Cheltenham district, which has its own peculiar forms. He suggested that a Palæozoic barrier might have separated the Dorset and Cheltenham areas.

In his interesting survey of the Inferior Oolite rocks Mr. W. H. Hudleston[3] dismisses the Dundry sections in a few words. He says: "In the present condition of the available

[1] 'Geology of the Bristol Coal-Field. Part 5, Jurassic Strata.' *Proc. Bristol Nat. Soc.*, new series, vol. ii., part iii. (1879), p. 279.

[2] '*Terebratula Morieri* in England,' *Geol. Mag.* (1878), p. 552.

[3] 'Gasteropoda of the Inferior Oolite,' *Pal. Soc.*, vol xl., p. 56, issued for 1886.

exposures it is by no means easy to construct an intelligible section of the Inferior Oolite in this remarkable hill."

In 1889, one of us (S. S. Buckman),[1] following somewhat on Mr. Walker's suggestion, compared both the brachiopods and the ammonites of Dundry, Dorset, and the Cotteswolds. He came to the conclusion that Dundry was more truly an outlier of the Dorset district than of the Cotteswolds, and he theorized as to the manner in which Dundry, during an interval of Jurassic history, might have been cut off from the Cotteswold area.

In the early part of 1892 the same writer[2] gave an abridged section of the Inferior Oolite of Dundry. He noticed 'the Ironshot,' 'the White Bed below the Iron-shot,' and 'the Nodular Bed.'

In 1893, as one result of the work done by us for the present paper, S. S. Buckman[3] gave an outline section of the upper part of Dundry Hill, to correlate its beds with Dorset.

In 1894 H. B. Woodward furnished a short account of the Dundry beds in his Survey memoir,[4] but he only made the following divisions :—

Building or Freestone beds. Ragstones.	Zone of *Ammonites Parkinsoni*.
Ironshot Limestones. Midford Sands.	Zones of *Ammonites Humphriesianus* and *Murchisonæ*.

In 1896 the authors of the present communication pre-

[1] 'The Relations of Dundry with the Dorset-Somerset and Cotteswold Areas during part of the Jurassic Period,' *Proc. Cotteswold Nat. F. Club*, vol. ix., pt. iv. (1889), p. 374.

[2] 'Inferior Oolite Ammonites,' *Pal. Soc.*, vol. xlv., p. 293, issued for 1891.

[3] 'The Bajocian of the Sherborne District,' *Quart. Journ. Geol. Soc.*, vol. xlix. (1893), p. 508.

[4] *Mem. Geol. Surv.*, 'The Lower Oolitic Rocks of England,' in 'The Jurassic Rocks of Britain,' vol. iv. (1894), p. 99.

sented a detailed paper on 'Dundry Hill: its Upper Portion, or the beds marked as Inferior Oolite (g 5) in the maps of the Geological Survey' to the Geological Society. This paper appeared in Vol. 52 of the Proceedings of the Society, November, 1896. Those who desire more detailed information concerning the geology of Dundry may refer to that paper.

Such is a short account of what has been done in connection with the geology of Dundry Hill. We now propose to give a summary of our present knowledge,[1] and in order that the structure of different portions of the hill may be better understood we present some generalized sections.

III. The Geological Structure of the Hill.

The structure of the western portion of the hill first demands consideration. The particulars may be given in the following manner; and in the margins are named the exposures where the beds may be observed:—

Section I.

The Western Portion of the Hill.

The Freestone Quarry near the Church.
(Mr. Towle's Quarry).

			ft. ins.	ft. ins.
Bathonian Age.	Coralline Beds.	1. White limestone in one thick bed —a crystalline rock of open texture. Corals, echinid spines, Polyzoa. This bed caps the quarry in certain places	1 6	
		2. Thin-bedded, whitish ragstones		

[1] We necessarily repeat some of the information given in our paper to the Geological Society. We are also glad to repeat that our best thanks are due to Sir J. H. Greville Smyth, Bart., and to J. H. Shorland, Esq., for their kind permission, enabling us to make the necessary excavations upon their properties; and that we are indebted to their tenants for much assistance in this matter.

Age	Hemera	Bed	ft. ins.	ft. ins.
BATHONIAN AGE.		with grey streaks along centres, in beds 2 or 3 inches or a little more, mixed with marl. *Zeilleria Waltoni*, *Terebratula globata*, corals	6 0	
			———	7 6
	THE FREESTONE BEDS.	3. Pale-grey, white, or yellow limestone, about 9 inches thick, passing downwards into compact, light-yellow ragstone ...	5 9	
		4. Compact pale freestone, the most valuable bed of Dundry stone, somewhat variable in thickness	12 0	
			———	17 9
	Clements' Yard.			
	GARANTIANÆ.[1]	5. Light-grey stone with *Acanthothyris spinosa*, exposed about ...	0 10	
		6. Rubbly marly limestone, slightly ironshot. *Astarte Manseli* ...	0 2	
			———	1 0
West End, near Castle Farm.				
BAJOCIAN AGE.	SONNINIÆ.	7. Planed-off top on some blocks. Yellowish-grey limestone, hard and well ironshot. *Lima Etheridgii*. *Lithodomi* at top ...	0 9	
		8. Whitish ironshot limestone, very small iron grains. Ammonitiferous bed. *Witchelliæ*,[2] etc. *Sonn.* cf. *fissilobata*	0 7	
		9. Hard, greyish, sparry ironshot limestone; often has a brown tinge. Perished ammonites of the *fissilobata*-type	0 2	
		10. Brown sandy parting. Large *Sonniniæ*, cf. *ovalis*	0 1	
			———	1 7

[1] The amount deposited during the times of the respective hemeræ is shown by this and the following hemeral names at the left hand, marking the last deposit of the date to which they belong.

[2] A light stone with *Witchelliæ* was exposed in a fissure of the Freestone quarry.

Age	Zone	Bed	ft. ins.	ft. ins.
Bajocian Age.	Discitæ.	11. Grey crystalline limestone in large blocks. *Lioceras, Hyperlioceras, Sonniniæ, Belemnites Blainvillei, Astarte excavata, Lima Etheridgii*	1 2	
		12. Laminated grey limestone, with ochreous clay streaks	0 2	
				1 4
Aalenian Age.	Concavi.	13. Light-grey crystalline limestone. *Lioceras intermedium, Rhynchonella Forbesi*, and belemnites	0 5	
		14. Soft, greyish, earthy limestone, with fragments of whorls of a *Sonninia, Lioceras concavum*	1 0	
		15. Irregular marl parting	0 3	
		16. Light-grey sandy limestone in two blocks, with brown earthy marl. *Terebratula Eudesi, Ter. cortonensis*, and *Ter. perovalis*	1 2	
		17. Clay parting	0 1	
		18. Light grey, nodular, sandy limestone and clay infillings between the blocks	0 7	
				3 6
	Bradfordensis and Murchisonæ	19. Light-grey, nodular limestone and clay infillings. *Zeilleria anglica* (Oppel) in the limestone	1 0	
		20. Do. more sandy; no fossils seen	3 0	
		21. Light-grey earthy limestone. *Ter. Eudesi, Trigonia striata, Lioceras*, cf. *bradfordense*	0 6	
		22. Clay parting. *Z. anglica*	0 1	
		23. Grey, earthy limestone, somewhat coarsely ironshot	1 9	
				6 4
	Opalini	24. Do. more coarsely ironshot. Large *Lima Etheridgii*. Scattered black phosphate concretions in the lower 6 inches ...		1 6

Age	Hemera	Bed	ft. ins.	ft. ins.
AALENIAN AGE.	AALENSIS	25. Blue, compact, argillaceous limestone. *Grammoceras subcomptum*; numerous Lamellibranchs and Gasteropods indeterminable; casts of *Cucullæa*, sp., *Inoceramus*, *Amberleya*, sp. ...		0 3
TOARCIAN AGE.	DUMORTIERIÆ	26. Greenish-blue clay, measured by the level and reckoned to be in all		50 0
	Excavation made lower down the hill by the roadside.			
	DISPANSI	27. Pinkish to grey, dense, earthy limestone—a few large iron specks. *Grammoceras fallaciosum*		0 4
	STRIATULI.	28. Greenish-grey, earthy limestone, coarsely ironshot. *G. striatulum*, Pectens, Belemnites...		0 2
	BIFRONTIS.	29. Blue, argillaceous limestone, irregularly specked, with large iron grains. *Hildoceras bifrons*, Belemnites. *Rhynchonella* sp. ...		0 2
	FALCIFERI.	30. Pinkish argillaceous limestone, very few iron grains. *Harpoceras falciferum*, *Dactylioceras commune*		0 2
PLIENSBACHIAN [1] AGE.		31. Greenish-blue clay visible		7 0

Beginning at the base, the first point to notice is the absence of the Marlstone, a deposit of the Spinati hemera—a fact also further confirmed for the western part of the hill by excavations at Elwell Spring giving the same result. As will be seen in later sections, the Marlstone is found in other portions of Dundry Hill interposed between beds 30 and 31, *i.e.* between the Pliensbachian clays and the beds of the Toarcian Age.

Next, the thin deposits (Nos. 27–30), yielding the same species of ammonites as the base of the "Cephalopod-bed"

[1] To replace Charmouthian, see note, p. 232.

of the Cotteswold range *plus* "Upper Lias," are important; and then the thick mass of overlying clay (No. 26) proved at the other end of the hill to have been deposited during the *Dumortieriæ* hemera, contemporaneously with the middle part of the Cotteswold Cephalopod-bed. All these deposits show a thickness of about 50 feet, which would have been formerly called "Midford Sands and Upper Lias."

The evidence concerning the deposits made during the *bradfordensis* and *Murchisonæ* hemeræ is not very satisfactory here, but *Zeilleria anglica* (see Nos. 19 and 22) marks a very definite horizon in Dorset[1]; it lived more or less contemporaneously with *Ludwigia Murchisonæ*, and perhaps died out just before *Lioceras bradfordense.*

Above the horizon of *Zeilleria anglica*, the next noticeable datum-line is that of *Sonninia* aff. *ovalis* (Quenstedt). Between these two horizons are certain beds with species of *Hyperlioceras* in the upper part, and species of the *concavum*-type lower down.

It is to be noted that the planed-off top, indicating denudation, appears on the upper surface of a bed which we term the 'Lower White Ironshot,' so that there is here a distinct non-sequence between the strata of the *Sonniniæ* hemera and the strata which directly overlie them, viz. the strata of the *Garantianæ* hemera. This gap in the sequence is partly filled by some strata met with in sections to be described presently. But the point to be noticed is that the beds of the *Sonniniæ* hemera in the western part of the hill are not capped by any representative of the Ironshot oolite.

The thick freestone beds of Dundry yield a stone of considerable economic importance; they are capped by a few feet of coralliferous stone and marl, which we have termed the

[1] See S. S. Buckman, 'The Bajocian of the Sherborne District;' *Quart. Journ. Geol. Soc.*, vol. xlix. (1893), p. 489.

"Coralline beds." Several species of corals have been obtained from these deposits, as well as many specimens of *Zeilleria Waltoni*, and, less plentifully, *Aulacothyris carinata*, *Rhynchonella plicatella*, *Rh. subtetraedra* ; and, from the same bed elsewhere, *Acanthothyris panacanthina* rarely.

Attention must now be directed to the south-western portion of the Hill, where the upper beds may again be seen.

There are two exposures southward from Dundry church: one is Barns Batch quarry, at the bend in the road to Littleton on the south flank of the hill, and the other is about two fields eastward in a small clump of trees. On the 6-inch Ordnance map it was marked as a "gravel pit"; we have called it "Barns Batch Spinney."

SECTION II.

The South-western Portion of the Hill.

		ft. ins.	ft. ins.
Barns Batch.			
	1. Pale grey, crystalline, coarse-textured limestone and ragstone massively bedded, but somewhat rubbly in places,[1] thickness about 19 ft.		
Barns Batch Spinney.			
	(To top of hill, showing at intervals beds like those at Barns Batch), about ...		45 0
	1*a*. Irregularly, thinly laminated white crystalline limestone, with numerous corals, large *Thamnastræa*, small *Ostrea*, *Pecten* sp., *Lithodomi*, *Cidaris Fowleri*, *Terebratula* sp., *Rhynchonella* sp. ...		5 0
SONNINIÆ.	2. Irregularly-bedded, finely ironshot limestone, pale pinkish grey. A line of large smooth ammonites (*Sonninia fissilobata?*) 5 to 6 inches from top, *Lima Etheridgii*, *Myacites Jurassi*, *Ctenostreon pectiniforme*, *Trigonia striata*		

[1] There were obtained: Corals, *Terebratula* aff. *globata*, and the same kind of *Ostrea* as in the Coralline beds of the roadstone quarries.

		ft. ins.	ft. ins.
	(cast), *Pecten* sp., *Sphaeroceras Brocchi*, *Belemnites*		1 2
DISCITÆ	3. Laminated sandy limestone parting. *Lima Etheridgii*, *Myacites Jurassi* ...	0 6 to 7	
	4. Compact, nodular, greyish limestone. *Sonninia*, *Hyperlioceras* sp., *Pecten* sp., *Gresslya abducta*, *Myacites Jurassi* ...	0 8 to 9	
	5. Pale grey, compact, nodular limestone with earthy partings, in four blocks ...	1 11	
			3 3
CONCAVI.	6. Pale yellowish, compact, finely ironshot limestone. *Lioceras concavum*, *Modiola Sowerbyana*, *Terebratula Eudesi*... ...		3 9
BRADFORDENSIS AND MURCHISONÆ.	7. Brownish, sandy, finely ironshot limestone. A large smooth ammonite and *Terebratula Eudesi* (? *shirbuirniensis*) near the top		4 3

The deposits marked Nos. 2–4 can be correlated in a general way, without any difficulty, with the deposits shown in other sections. No. 2 is the Lower White Ironshot bed on the horizon of *fissilobata-ovalis*, the time of its deposition being that of the *Sonniniæ* hemera. Our opinion of the time of the deposition of the other beds, and consequently of their correlation, is shown in the margin.

It is important to notice that here also there is not *the* Ironshot, nor is the underlying *Witchellia*-bed present—these beds have, presumably, been removed by denudation. Therefore the next underlying bed, the deposit of the *Sonniniæ* hemera, is capped non-sequentially by a deposit which we consider is approximately contemporaneous with the Freestone in the large quarry near the church; but we are much puzzled as to the position of the 19 feet of stone at Barns Batch, or of presumably a much greater thickness of deposit above Bed 1 of the Spinney section. To the top of the hill on a fairly steep slope above this section there are some 45 feet of rock. Part of the apparent thickness of the rock on this slope might be due to repetition of the beds by step-faults;

but we know that at least 20 feet of rock must be present on the evidence of Barns Batch. If the thickness be no more than this, it is possible that all these beds were deposited contemporaneously with the Freestone; but if the thickness be greater, two interpretations present themselves: (1) There was a considerable thickness of limestone deposited subsequent to the Coralline beds; or (2) all this limestone was deposited before the Coralline beds, and therefore a much greater thickness of a more coarsely-textured stone was laid down at the south-western portion of the hill, while 20 feet of Freestone were being deposited near the church, and about 4 feet of limestone in the roadside quarries.

The solution of the question may be a matter of economic importance (see p. 221); and it is certainly of scientific interest—especially if the first supposition prove correct.

That portion of the hill which is crossed by the Main-road, and lies near East Dundry village, may now be dealt with.

Section III.

The Middle of the Hill.

The Northern Main-road Quarry near the "Butchers' Arms." [1]

		ft.	ins.
Coralline Beds.	1. Rubble and soil	3	0

[1] The exposure at the Southern Main-road quarry gives very similar details to this one; but, capping the strata of the *Sauzei* hemera, there is the following bed:—

		ft.	ins.
Garantianæ.	1. Grey, crystalline, somewhat ironshot 'ragstone.' *Astarte Manseli, Rhynch. subtetraedra, Aulacothyris carinata.* Corals	0	10

This deposit is not found in the Northern Main-road quarry.

		ft. ins.	ft. ins.
	2. Grey, crystalline, lenticularly-bedded, coralline limestone. Many corals ...	2 6	
	3. Greenish clay with dark crystalline limestone. *Zeilleria Waltoni*, *Terebratula* sp. nov., *Acan. panacanthina*, and a number of micro-brachiopoda	2 0	4 6
Equivalent of Dundry Freestone.	4. Whitish, regularly and thinly-bedded, compact limestones with small iron specks. (The top bed bored.)		4 0
Sauzei.	5. "The Ironshot Oolite." Yellowish-brown ironshot limestone—the well-known fossiliferous horizon. (The top flat and planed off.) *Stephanoceras Sauzei*, *Sonniniæ*, *Acanthothyris paucispina*, and many other ammonites, gasteropods and lamellibranchs		1 0
Witchelliæ.	6. Whitish, argillaceous, ironshot limestone. Many lamellibranchs and ammonites, particularly *Witchelliæ*	0 5	
	7. Brown marl	0 2	
	8. Brown-grey ironshot limestone. Belemnites, bivalves, and univalves ...	0 7	1 2
Sonniniæ.	9. Grey ironshot limestone, with many *Sonniniæ* and *Witchelliæ*	0 8	
	10. Brown-yellow shelly limestone. At the top of this there is often a bed of brownish sand about 3 inches thick with numerous more or less perished *Sonniniæ* of the *ovalis*-type, marking a conspicuous horizon in the quarry	0 9	1 5
Discitæ.	11. Yellowish-brown limestone with compact ochreous marl. Umbilicate *Hyperlioceras*, *Terebratula Eudesi*, and *Ter. cortonensis*	1 0	
	12. Yellowish-brown limestone with small ochreous specks. *Terebratula Eudesi*	0 5	1 5
Concavi ?	13. Light-coloured limestone, pale grey below, yellow-ochreous and marly above	1 0	

Rackledown[1] *Farm.*

Zone	Bed	Description	ft. ins.	ft. ins.
Concavi.	13*a*.	Greyish limestone, about	2 0	
				3 0
Bradfordenis and Murchisonæ.	14.	Very dense, pinkish-red, crystalline limestone. The top of bed somewhat planed off and covered with ferruginous nodular lumps. *Zeilleria anglica*, *Rhynchonella Stephensi*?, *Myaeites* aff. *Jurassi*[2]	4 9	
	15.	Tough crystalline limestone, yellowish-grey, with scattered iron-grains ...	1 7	
	16.	Earthy limestone with scattered iron-grains, with interwedgings of irregular, compressed, ironshot, sandy clay. *Ludwigia* cf. *obtusa*, on spoil-heap with matrix similar to this bed	0 5	
				6 9
Opalini?	17.	Pinkish-grey, ironshot, somewhat crystalline limestone. *Pholadomya fidicula*		2 8
East Dundry Village.				
Dumortieriæ.	18.	Stiff clays with grey sandstone bands by the "Rookery" and above "Spring Farm"		
(Dispansi to Bifrontis.) Falciferi.	19.	An isolated block of the *bifrons*-beds—a pinkish stone, coarsely ironshot. *Harpoceras* sp.		55 0
	20.	Yellowish clay.		
	21.	Pinkish-grey earthy stone. *Pseudolioceras* sp. 5 inches.		
Spinati and ? Margaritati.	22.	Strongly ironshot, somewhat variable, massive stone-block, with belemnites, *Pseudopecten æquivalvis*, *Terebratula punctata*, and *Ostrea* in bottom 2 feet		5 6

Note.—The Marlstone, where it outcrops on the opposite side of the valley, contains *Amaltheus margaritatus* and *Rhynch. tetraedra*.

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[1] On the 6-inch Ordnance map spelt "Rattledown."

[2] From this bed, judging by matrix, a fine *Ludwigia* aff. *obtusa*, Quenstedt, in the Bristol Museum, was obtained; also the specimens of *Cirrus*.

There are three noticeably ironshot beds at different horizons—Nos. 5, 19, and 22—but they are all very different both in lithic characters and in the fossils they contain. This is a matter of importance.

The Marlstone Rock outcrops in the bank of Spring Farm rickyard, in the middle of East Dundry, and, as it forms a small feature, it may be traced along the valley below the exposure of the Ironshot Oolite.

This outcrop is a point of very considerable importance. It is evident that the officers of the Geological Survey mistook this rock, which is an ironshot oolite, for "the Ironshot Oolite," the noticeable fossiliferous bed of Dundry Hill, whereby they confused the bottom bed of this Section with a bed which is 70 feet above it. Then, acting on this supposition, and knowing there would be so much of the "Inferior Oolite" below the "Ironshot," they drew the base-line of the "Inferior Oolite" somewhat below the outcrop of the Marlstone Rock, with this result—that they have coloured in their map as "Inferior Oolite" not only areas occupied by what they call "Midford Sands" or "Upper Lias" in other districts, not only Middle Lias, but even in all likelihood a part of what they would term Lower Lias. And in this way they have made the Inferior Oolite in places—for these remarks apply to most of the hill—nearly 150 feet thick: that is, from where they draw their line up to the top of the hill. The "Inferior Oolite" base-line should have been drawn at the base of No. 17, about 15 feet below the outcrop of the Ironshot Oolite; whereas it is drawn in the Geological Survey maps some distance below the outcrop of bed 22—in fact, nearly 100 feet too low down.

The bed No. 14 is hard and massive—very distinct from the rubbly condition to which the other rocks of the Rackledown exposure have been reduced. It was certainly deposited during the *Murchisonæ* hemera, and part of it, perhaps, during the *bradfordensis* hemera; but we have no evidence on the latter head.

The horizon of *Sonninia fissilobata-ovalis* (bed 10), which is well marked, may be noted as a very good datum-line from which to commence the correlation of the strata in the upper portion of this section with those of the western end of the hill. But the most noticeable beds are those which yield a fine series of *Witchelliæ*, and the overlying Ironshot Oolite, yielding *Sonniniæ* of the *propinquans*-type, with "*Stephanoceras*" *Sauzei*. These beds are wanting from the western portion of the hill; but in this part they have escaped "The Bajocian denudation."[1] Still, there is a non-sequence between beds 5 and 4, and this gap is not filled by any strata shown in any of the sections at Dundry. In order to make the sequence complete, strata laid down during the *niortensis-Humphriesiani* hemeræ should be present.[2]

An interesting fact, and one of economic importance, concerning this section is the great attenuation, together with change in character, of the deposit contemporaneous with the freestone of the quarry near the church. In the middle of the hill the freestone deposit is only represented by thin-bedded limestones about 4 feet in thickness.

It is necessary now to pass to the eastern end of the hill.

[1] See p. 219.

[2] See S. S. Buckman, 'The Bajocian of the Sherborne District,' *Quart. Journ. Geol. Soc.*, vol. xlix. (1893), p. 500, section of Frogden Quarry.

SECTION IV.

The Eastern Portion of the Hill:—A. Western side of Maes Knoll.

Maes Knoll (the eastern end of Dundry Hill).
The western side just south of the Tump.

		ft. ins.	ft. ins.
	A gentle grass-covered slope from the top of the hill, concealing rock ...		6 0
GARANTIANÆ.	1. Yellowish limestone, thickly speckled with iron grains. *Limatula gibbosa*, *Acanthothyris spinosa*, *Montlivaltia lens*	1 4	
	2. Pale grey crystalline limestone with numerous large subangular iron grains, and with small lumps of a bluish-grey sandstone nearly at the top. *Montlivaltia*, *Acanthothyris spinosa*, *Limatula gibbosa*, *Ctenostreon pectiniforme*, *Pholadomya* sp., *Trigonia* sp.	0 5	
	3. "The Conglomerate-bed." Pale grey crystalline limestone, containing derived lumps of a bluish-grey sandstone, generally bored by *Lithodomi*, and pieces of an oolitic, limonitic ironstone. *Rhynchonella subtetraedra*, *Astarte Manseli*, *Myoconcha crassa*, *Trigonia* aff. *costata*, *Limatula gibbosa*, *Gouldia ovalis*, *Cucullæa* sp., *Opis lunulatus*, *Ostrea sp.*, *Pecten* sp., *Lima* sp., *Pseudomelania coarctata*, *Cerithium subscalariforme*, *Atraphrus obtortus*, *At. Labadyei*, *At.* sp., *Trochus biarmatus*, *Natica* sp., *Belemnites* sp., *Parkinsonia* cf. *Garantiana*[1] and *Strophodus* sp., are indigenous. There are derived fragments of *Grammoceras* aff. *aalense*; much rolled fragments of *Hildoceratidæ*, presum-		

[1] Slightly more umbilicate, a little more compressed.

		ft. ins.	ft. ins.
	ably *Grammoceras* spp., and fragments of *Dumortieriæ*, mostly showing a matrix of bluish-grey sandstone ...	0 6	
		——	2 3
Dumortieriæ.	4. Compact, bluish-grey, argillaceous sandstone in two beds. It contains fragments of 2 or 3 species of coarsely and finely costate *Dumortieriæ*. Exposed about 1 ft.		
Maes Knoll. 70 *yards east of Spinney below the Tump.*			
	5. Clay and sandstones ... ... about		60 0
Dispansi.	6. Grey argillaceous stone with scattered iron-grains. Belemnites		0 11
Striatuli ?	7. Purplish-brown to drab, speckled stone with belemnites, shell sections, ammonites with a drab matrix		0 7
Variabilis.	8. Upper bed of blue rock with brown iron-grains and ferruginous lumps ..	0 5	
	Lower blue rock, scattered iron-grains, ferruginous lumps, and lumps of a dense pink stone	0 2	
		——	0 7
Spinati.	9. "Marlstone Rock." Very dense rock, a ferruginous oolite. *Pseudopecten æquivalvis.* The lower four inches of this bed is a grey sandy rock, while the top four inches is richly ironshot, with red and yellow tints		1 7
Margaritati ?	10. Grey, thinly laminated, but massive unfossiliferous sandstone, found apparently at its base		1 6

Immediately above the *Dumortieria*-beds lies the remarkable conglomerate bed formed during the *Garantianæ* hemera—specimens of *Parkinsonia* cf. *Garantiana* having been found in it. Here, then, is a case of very noticeable non-sequential deposition, denudation being presumably the agency which has removed whatever strata may have been deposited; and in all probability, considering the short distance,—for the Ironshot Oolite is found in an arable field only 7 furlongs to the west—there was originally at Maes Knoll a sequence of deposits similar to that found in the middle of the Hill (see Section III.).

This denudation, no doubt, was in progress partly during Bajocian time, and therefore it was contemporaneous with what was called "Bajocian denudation" by one of us.[1] But it is evident that the progress of erosion was continued into Bathonian time, and that the conglomerate bed of Maes Knoll was largely formed out of derived materials during the time of a post-Bajocian or Bathonian denudation.

We give details of another exposure—on the eastern side of the hill—because it is remarkable for one thing—the absence of the Marlstone; so that at this, the extreme eastern point, was found a condition of things similar to what obtains at the western end of the hill.

Section V.

The Eastern Portion of the Hill :—B. *The eastern side of Maes Knoll.*

Maes Knoll, on the eastern flank, overlooking New Barn Farm.

		ft. ins.	ft. ins.
Dumortieriæ.	1. Stiff, greenish clay with argillaceous sandstone, extending up the hill.		
	2. Pale, yellowish-green sandstone, fragments of *Dumortieria* aff. *prisca*, *Dum.* aff. *radians*, *Hudlestonia* aff. *serridens*	0 6	
	3. Bluish and yellowish clay	2 6	
		——	3 0
Dispansi.	4. Yellowish, argillaceous sandstone; *Hammatoceras*, sp.	0 5	

[1] See S. S. Buckman, 'The Bajocian of the Mid Cotteswolds,' *Quart. Journ. Geol. Soc.*, vol. lvi. (1895), p. 431.

		ft. ins.	ft. ins.
	5. Bluish arenaceous clay	1 0	
	6. "The Upper *Rhynchonella*-bed." Yellowish-brown iron-speckled stone. *Rhynchonella* aff. *Moorei*	0 5	
STRIATULI. (2 in. of bed 7; the other 4 inches of the 6″ belongs to *Dispansi*).	7. Brown, irregularly iron-speckled stone. *Grammoceras Struckmanni*, and canaliculate *Belemnites* in the upper portion. *Haugia* aff. *Eseri*, *Gramm. striatulum*, and numerous cylindrical belemnites at the base, and about 2 inches up. *Rhynchonella* aff. *Moorei* in the bed. Thickness 6″...	0 4	
		——	2 2
		0 2	
	8. Dark brown, ironshot stone. *Grammoceras striatulum*, *Belemnites* ...	0 6	
		——	0 8
VARIABILIS.	9. Stone with similar matrix. Fragments of several species of costate tuberculate *Haugiæ* aff. *jugosa*. *Zeilleria* aff. *anglica*	0 3	
	10. Stone with similar matrix. *Haugia* aff. *jugosa*. Large belemnites	0 2½	
	11. "The Lower *Rhynchonella*-bed." Stone with similar matrix, *Haugia* sp., *Rhynch.* aff. *Moorei*.[1] The bed also contains the following derived fossils, showing a pink matrix, and more or less coated with iron oxide. *Hildoceras bifrons*, and especially the thin form. *Dactylioceras*, spp.; fragments of *Harpoceras* aff. *falciferum*; also irony lumps...	0 4	
	12. Compact, blue, irregularly ironshot limestone with iron lumps, bearing worm-tracks. Derived lumps of a pink matrix, and derived fossils—same as in bed above. *Belemnites*, smooth *Pectens*, *Rhynchonella* ...	0 4	
		——	1 1½

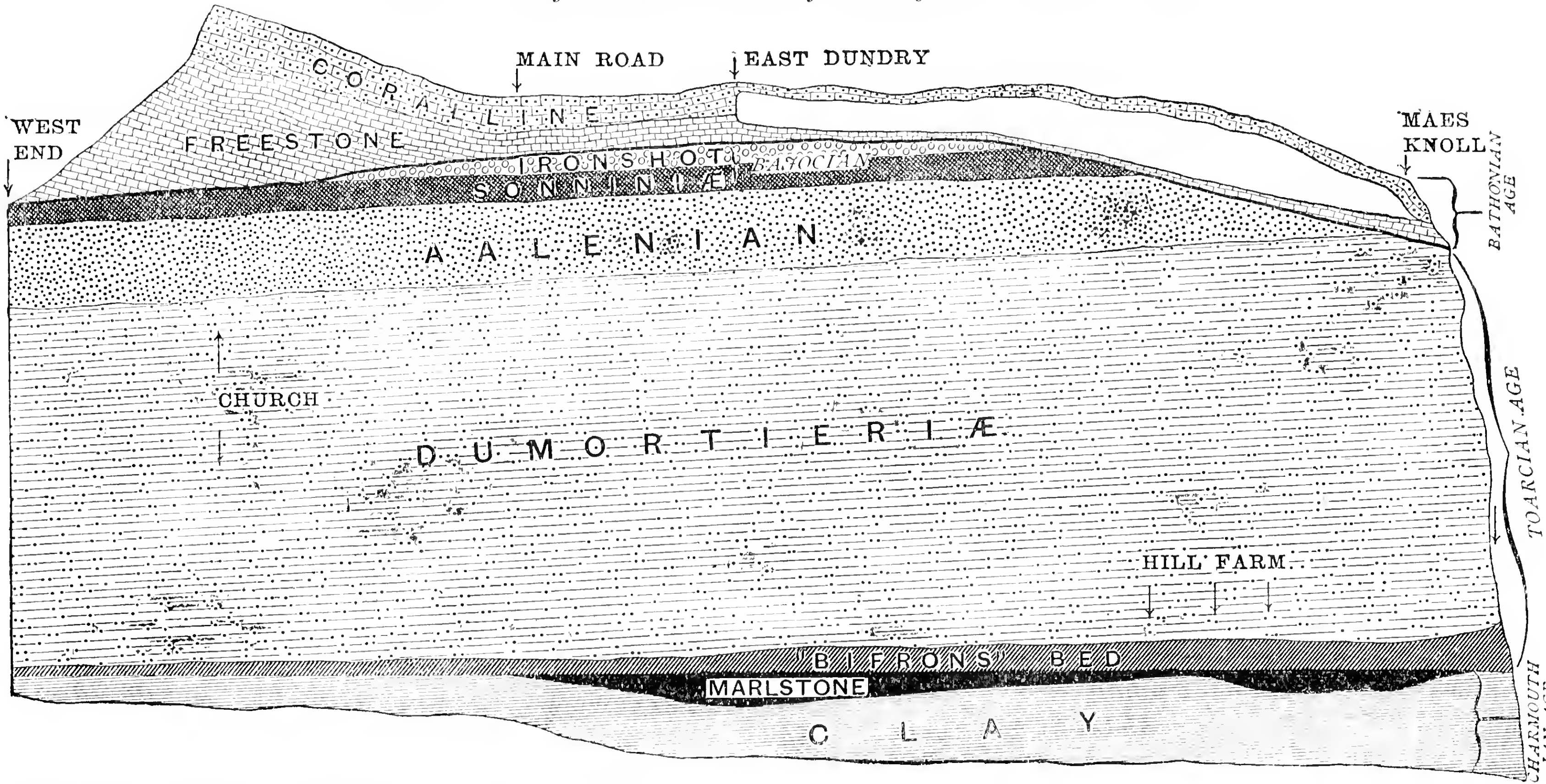
[1] It is a different form from the *Rhynchonella* in bed 10.

		ft. ins.	ft. ins.
Bifrontis.	13. Compact argillaceous limestone, blue and ironshot for the upper 5 inches, and pink, not ironshot, for the lower 3 inches. The blue part contains: *Hildoceras bifrons*, *Dictylioceras* and *Harpoceras falciferum* and *Rhynchonella*, coated with iron oxide, together with derived limonitic lumps. The pink portion has a matrix similar to that of the derived fossils in the beds above, and it contains *Harpoceras falciferum* and *Harp. exaratum*. Thickness 8 inches	——	0 5
Falciferi lower 3 inches.		0 3	
	14. Pink clay. *Harpoceras* aff. *Strangwaysi*, *Pseudolioceras ?* sp.	0 6	
	15. Pale drab, earthy stone	0 5	
	16. Pinkish-drab, ironshot, earthy stone, with lumps of greenish stone bored by *Lithodomi*, and covered with iron-oxide. *Dactylioceras*, and belemnites	0 9	
		——	1 11
	17. Greenish clay proved by trenching about 34 feet (vertical) without a sign of Marlstone or of any hard rock.		

The fossiliferous strata associated with the "*bifrons*-beds" are interesting for the regular sequence of different ammonites. There are at this eastern end of Dundry Hill thin fossiliferous deposits laid down during the *dispansi*, *striatuli*, *variabilis*, and *bifrontis* hemeræ, of a similar thickness to the same deposits found at the western end. During the earlier portion of the *variabilis* hemera local denudation was evidently in progress, as is shown by the condition of the deposits numbered 11 and 12; the *bifrons*-beds have evidently been broken up and redeposited just before or during the time of *variabilis*.

Immediately above these thin stone beds (Nos. 4–16 of the above Section) occurs a considerable argillaceous deposit,

Table I. Diagrammatic Section of Dundry Hill—West to East.



We must acknowledge our indebtedness to the Council of the Geological Society for their kind permission to use this block; and we tender them our thanks for the courtesy. The suggestion of false bedding has arisen from the engraver replacing colour by lines.

with a species of *Hammatoceras* at the base, and species of *Dumortieria* in its main mass. This is what we called the "*Dumortieria*-beds," and it is the same deposit as that which we found at the western end of the hill.

IV. Diagrammatic Section of Dundry Hill.

The sections of which we have given details above, and other exposures which we noted in our communication to the Geological Society, enable us to construct the diagrammatic section of Dundry Hill, as shown on the foregoing page.

Concerning this diagram we would make the following remarks :—

We have taken the base of the *bifrons*- and associated beds as a datum level.

We have found, as the result of numerous trials with the level and many investigations, a thickness for the *Dumortieria*-beds of 50 feet at the western end, 55 feet at East Dundry, and 60 feet at Maes Knoll.

We have found the Marlstone only in the eastern part of the hill, east of the main road, and no signs of it west of the main road. It appears to be a bed which fluctuates considerably in thickness ; but perhaps the fluctations shown in the diagram may be partly attributed to the imperfect state of the exposures. We know that it fails altogether at the extreme eastern end of the hill, and also at the western end ; but it must be remembered that the exact point of its westerly disappearance, as shown on our diagram, is only conjectural.

We find at East Dundry the full sequence of Aalenian deposits, and of Bajocian until the *Sauzei* hemera—the Iron-shot Oolite. We know that at Maes Knoll the Bathonian, represented by beds of the *Garantianæ* hemera, rests directly upon the Toarcian—*Dumortieria*-beds, and that no deposits of Aalenian or Bajocian age are present. Consequently the Bajocian and Aalenian beds must successively disappear between East Dundry and Maes Knoll, presumably on account of denudation; but where, we can only suggest approximately on our diagram. However, we have found the Ironshot rubble in a ploughed field half a mile east of Walnut Farm.

West of East Dundry *the* Ironshot Oolite is found in the quarries on the Main-road; but it does not extend to the freestone quarry near the church. How far east of the main road it disappears we can only suggest in the diagram, since we have no data after passing the north roadside quarry.

The line of Bajocian denudation is consequently shown in our diagram with a slight easterly rise from the west end of the hill to East Dundry; then it continues practically level for a space, and finally falls with an easterly dip to Maes Knoll. It is indicated by a thick dark line.

The one other point in connection with this diagram which demands our attention is the rapid easterly attenuation of the freestone. We allude further to the economic aspect of this matter (see p. 220).

V. The Stratal and Faunal Sequence.

The structure of Dundry Hill and the sequence of its deposits—in the upper portion—having been given, it is now possible for us to construct a generalized Table of the full sequence of rocks to be met with in the hill, to assign to these rocks the dates of their deposition, and to give, in a Faunal Table, combined therewith, the names of different organisms which lived during the various portions of time (see Table II. facing this page).

Epochs	Ages	Hemerae	Deposits made during the stated times	Cephalopoda[1]	Brachiopoda	Gasteropoda[2]	Lamellibranchiata	Echinodermata, Corals, etc.
N[illegible]-JURASSIC	BATHONIAN	*Homœo.*	Possibly the Barrs Batch strata		*Zeilleria Waltoni* *Acanthothyris paucispina* *Terebratula globata* † *Rhynchonella subtetraedra* *Terebratula decipiens?* * *Terebratula sphæroidalis*. *Acanthothyris spinosa* *Terebratula* a feebly biplicate, ovoid form of the *punctata* group *Rhynchonella plicatella*. *Terebratula* aff. *Phillipsi*, but shorter and less plicate. *Acanthothyris carinata*. *Rhynchonella* aff. *parvula*.	*Pleurotomaria Palæmon* (d'Orb.)	*Trigonia costata* (Sow.) *Lithodomus inclusus*, Phill. *Ostrea acuminata*, Sow. *Lima*, sp.	*Pentacrinus Milleri*, Austen. *Magnotia Forbesi*, Wright *Hemicidaris granulosa*, Wright. *Cidaris Fowleri*, Wright „ *Bouchardi*, Wright **Holectypus hemisphæricus*, Ag * *Clypeus sinuatus*, Ag. *Hyboclypus ovalis*, Wright *Stomechinus intermedius*, Ag „ *bigranularis*, Lam. *Isastræa Richardsoni*, E. & H „ *Lonsdalei*, E. & H „ *tenuistriata*, M'Coy „ *explanata*, M'Coy *Thamnastræa Defranciana*, Mich „ *Terquemi*, E. & H *Latimæandra Flemingi*, E. & H. *Montlivaltia lens*, E. & H. *Glyphæa rostrata?* *Stropholia* sp.
		Post-Garantianæ. (The exact date is uncertain.)	The Coralline beds—a coralliferous stone mixed with much marl, occupying the highest parts of the hill; its upper portion removed by recent denudation. The Freestone—a local deposit of stone of economic value passing laterally into thin beds of no value, except as inferior road-stone, which we have called "Freestone equivalent."					
		Garantianæ	A thin deposit not always to be detected—the Conglomerate bed of Maes Knoll.	*Parkinsonia garantiana*, d'Orb *Sphæroceras* aff. *Brongniarti*, Sow.	† *Rhynchonella subtetraedra*. *Acanthothyris spinosa*. *Rhynchonella* aff. *angulata*, Sow *Terebratula* between *globata* and *Hollandæ*. *Zeilleria*, sp. cf. Davidson, Suppl. pl. xxiv. figs. 16, 17, also cf. *Hughesi*.	*Pleurotomaria Palæmon*, d'Orb. *Pseudomelania* aff. *coarctata*, Desl *Alaria Labadyei*, d'Arch. „ *obtusus*, Hudleston. *Trochus biarmatus*, Munst *Natica bajocensis*, d'Orb *Trochus dimidiatus*, Sow. *Amberleya* aff. *ornata*, Sow.	*Lima Lycetti*, Laube „ *semicircularis*, Goldfuss *Astarte* aff. *elegans*, Desh. „ *Manseli*, Buckm. *Limatula gibbosa*, Sow. *Gouldia ovalis*, Quenstedt. *Ctenostreon pectiniforme*, Sow. *Trigonia costata*, Sow *Opis angulatus*, J. Buckman † „ *lunulatus*, Sow *Trigonia* cf. *Moretoni* and *Waltoni*, Lycett. „ *duplicata*, Lycett.	
		Niortensis.	No deposits of this date have been found on the hill	Belemnites.				
	BAJOCIAN	*Humphriesianæ*	The same as above. If any deposit was made it was removed by the denudation which took place during this or the hemera afterwards					
		Sauzei	The Ironshot—a deposit which the Bajocian denudation has removed from most of the hill.	†*Stephanoceras* [illegible], J. de C. Sowerby. *Stephanoceras Sauzei*, d'Orb. † „ *Brakenridgii*, J. de C. Sowerby *Stephanoceras* aff. *Bayleanum*, Oppel. *Stephanoceras*, a crassicostate form. †*Sonninia corrugata* „ *mesacantha* *Oppelia præradiata*, Douvillé. **Cadomoceras*, sp. †*Sonninia Sowerbyi* (Miller). *Belemnites* [illegible], Voltz „ *ellipticus*, Miller. * „ [illegible] † „ [illegible] **Nautilus ornatus*, Foord and Crick.	*Terebratula* aff. *Hartmanni*. *Acanthothyris paucispina*. A somewhat flattened *Terebratula* aff. *sphæroidalis*. †*Rhynchonella dundriensis*, S. Buckm.	*Pleurotomaria elongata*, Sow. „ [illegible], d'Orb. „ *ornata*, var. Mon[illegible] „ [illegible] „ *ornata*, Sow „ *granulata*, Sow. † „ *distinguenda*, Tawney. „ *fasciata*, Sow. (*) „ *sulcata*, Sow. „ *subreticulata*, d'Orb „ *Proteus*, Desl. „ *abbreviata*, Sow † „ [illegible], Hudlest. (*) „ [illegible], d'Orb. (*)*Trochus Zetes*, d'Orb. *Alaria* [illegible], Sow. *Pseudomelania* [illegible], Sow. *Cerithium subscalariforme*, d'Orb. † *Spinigera* [illegible], Tawney. † [illegible] *dundriensis*, Tawney.	*Goniomya angulifera*, Sow. *Astarte multicostata*, S. Buckm. *Myacites jurassi*, Brong. *Gervillia Hartmanni*, Munster. [illegible], Sow. *Pholadomya* [illegible], Whidborne. „ [illegible], Roemer. „ [illegible], Sow. †*Hinnites* [illegible], Whidborne. *Opis lunulata*, Sow. *Cucullæa oblonga*, Sow. „ [illegible], Sow. „ [illegible], Phill.? *Ostrea flabelloides*, Lam „ *Marshi*, Sow. „ *explanata*, Munster. *Lima alticosta*, Ch. & Dew. *Hinnites abjectus*, Phillips *Ctenostreon pectiniforme*, Sow. [illegible], Munst.	*Serpula grandis*, Munster [illegible], sp. (spine).
		Witchellia.	The Upper White Ironshot—the *Witchellia* beds.	† *Witchellia laeviuscula* „ aff. *Sutneri* *Sphæroceras Brocchi* (Sowerby)		*Pleurotomaria actinomphala*, Desl. „ [illegible], Desl. „ *ornata*, Munster. „ [illegible], Hudleston. † *Amberleya ornata* Sow. † *Alaria dundriensis*, Tawney. †*Natica dundriensis*, Tawney	*Opis similis*, Sow. *Myoconcha crassa*, Sow. [illegible], d'Orb. *Pecten* [illegible], Sow. *Cardium* [illegible], M. & L.	
		Sonniniæ.	The Lower White Ironshot—the [illegible] horizon	*[illegible], sp., S. P. Woodward, non Sowerby. (*) *Sphæroceras*, the small form called *Brocchi* by Sowerby † *Sonninia Browni*, Sowerby. „ [illegible] „ *Stephani* (S. Buckm.) „ *ovalis* (Quenst.). „ aff. [illegible] *Sonninia* [illegible] [Bridge]. [illegible] *compressum* (Ethe[illegible]	*Terebratula* aff. *Uptoni*, S. Buckm. [Mr. J. W. D. Marshall.] *Terebratula* [illegible], S. Buckm [Mr. J. W. Tutcher.]		*Lima Etheridgei*, Wright. *Myacites jurassi*, Brong. *Ctenostreon pectiniforme*, Sow. *Trigonia striata*, Sow. *Gresslya abducta*, Phill *Pholadomya Murchisoni*, Sow.	
		Discitæ.	The Grey Limestone and Marl beds—the *discites* and *concavus* beds—the *Terebratula Eudesi* beds.	*Lissoceras Etheridgei*, S. Buckman *Hyperlioceras* aff. *discites*. „ aff. *Walkeri*. *Lioceras intermedium* *Belemnites Blainvillei*.	*Terebratula cortonensis*, S. Buckm. *Terebratula Eudesiana*, S. Buckm. *Rhynchonella Forbesi*, Dav. ("immediately above stone with *Tereb. Eudesi*," E. Wilson).		*Unicardium elegans*, Sow. „ [illegible], Sow *Lima Etheridgei*, Wright. *Myoconcha crassa*, Sow. „ *complana*, Whidb.	
		Concavi.		*Lioceras concavum* „ *V. scriptum*.	†*Terebratula Eudesi*, Oppel. † „ *perovalis*, Sow. „ *cortonensis*, S. Buckm		*Modiola Sowerbyana*, d'Orb. *Myoconcha crassa*, Sow. „ *complana*, Whidb. **Cypricardia* [illegible], d'Orb.	*Serpula* [illegible], Munster, attached to *Terebratula cortonensis* and *T. Eudesi*.
	AALENIAN	*Bradfordensis & Murchisonæ.*	The hard irony beds exposed as massive rock at Rackledown Quarry.	*Lioceras* cf. *bradfordense* *Ludwigia* [illegible] (Quenstedt).	*Terebratula* [illegible] ? „ *Lessi*. † „ *Whitakeri*, Dav †*Zeilleria anglica*, Oppel *Rhynchonella* aff. *Stephensi*, Dav. (*)	*Pleurotomaria Mopsa*, d'Orb. † „ *Stoddarti*, Tawney. † „ *dundriensis*, Tawney. „ [illegible], d'Orb „ cf. *subdecorata*, Munst. „ *Anglica*, d'Orb. „ *punctata*, Sow ? † *Cirrus nodosus*, Sow † „ *pyramidalis*, Tawney. ?† „ *Leachi*, Sow. „ *Calisto*, d'Orb *Amberleya Stoddarti*, Tawney.	*Trigonia striata*, Sow *Myacites* aff. *jurassi*, Brong. *Opis trigonalis*, Sow. **Cypricardia cordiformis*, Desh.	
		Opalini & [illegible].	The bottom beds (of stone)	*Grammoceras* [illegible], (Branco). (Branco). *Grammoceras* aff. *lotharingicum* [illegible] „ *aalense* (Zieten) „ aff. *aalense* (Zieten) „ [illegible], S. Buckman, cf. M[illegible] pl. 33, fig. 8 *Grammoceras subcomptum*.	*Rhynchonella*, sp., a kind of dwarf form of *cynocephala*, S. Buckm. *Rhynchonella Stephensi* *Terebratula* aff. *infra-oolithica*, E. Desl. ? *Waldheimia Blakei*.		*Lima Etheridgei*, Wright *Pholadomya* [illegible], Sow.	
NEO-JURASSIC	TOARCIAN	*Dumortieriæ.*	The Upper Clay beds—the *Dumortieria* beds.	*Catulloceras Dumortieri* (Thiollière). (Reinecke) *Dumortieria* aff. *radians* *Dumortieria* aff. *pusilla*, S. Buckman. *Hudlestonia* aff. *serrodens*.	?*Zeilleria* aff. *Lycetti*. *Rhynchonella Moorei*, Dav.			
		Dispansi.		*Hammatoceras*, sp., in the latter part of this hemera. *Grammoceras Struckmanni* „ *doerntense*, Denckm. Canaliculate belemnites.	*Rhynchonella* aff. *jurensis*, Dav., non Quenst.			
		[illegible]	The Blue Ironshot—the *Rhynchonella* beds or the *bifrons* beds.	*Grammoceras striatulum* „ [illegible] „ aff. *Struckmanni* *Haugia* aff. *Eseri*. Cylindrical belemnites	*Rhynchonella*, aff. *jurensis*, Dav., non Quenst.[3]			
		Variabilis.		*Haugia* aff. *jugosa*. Form of the *Lillia Lilli* type *Haugia*, n. sp., aff. *illustris*, Denckm.	*Zeilleria* between *Lycetti* and *anglica* *Rhynchonella* aff. *jurensis*, Dav., non Quenst., but a different form to those mentioned above			
		Bifrontis.		*Dactylioceras* aff. [illegible] „ aff. *subarmatum*, Dumortier. *Dactylioceras*, cf. *commune* *Hildoceras bifrons*.				
		Falciferi.	The Pink beds—the Upper Lias.	*Dactylioceras* aff. *commune*. „ aff. *annulatum*. *Harpoceras falciferum* (Sow.) „ *capellinum* (Quenst.) „ [illegible] (Sow.) „ aff. *Strangewaysi* *Pseudolioceras*?, sp. *Hildoceras Levisoni*				
		Spinati & Margaritati.	The Marlstone.	*Pleuroceras* aff. *solare*, Quenst *Amaltheus margaritatus*.	*Terebratula punctata*. *Rhynchonella tetraedra* „ *northamptonensis*. *Zeilleria indentata*?, fragment. *Rhynchonella* aff. *subdecussata*, Zittel, 'Geol. Beobachtungen aus den Central Apenninen,' pl. xiv. (2) fig. 12, 'Geogn. Pal. Beitr.,' vol. pt. ii., Munich 1869		*Pseudopecten æquivalvis*, Sow. *Gryphæa cymbium*, Lam.; or *Ostrea* [illegible] *Avicula*.	
	PLIENSBACHIAN		The Lower Clay bed.					

[1] Those marked † are type-forms named from Dundry specimens originally. Those figured from Dundry, but not specific types, are marked (*). Cephalopoda and Brachiopoda by S. S. Buckman.
[2] Gasteropoda, Lamellibranchiata, etc., by E. Wilson. [3] Said by Mr. J. F. Walker to be near his *Rhynchonella northamptonensis*, mentioned but not figured, Geol. Mag. dec. iii. vol. ix. p. 442 (1892).

From the Stratal portion of this Table it may be seen that there is a break in the due sequence of deposits at Dundry Hill. As a matter of fact, this break in the sequence is least in the middle of the hill; but to the west it is greater, so that strata of the *Garantianæ* hemera rest directly upon strata of the *Sonniniæ* hemera; while to the east it is very marked—the strata of the *Garantianæ* hemera resting directly upon those of the *Dumortieriæ* hemera.

In regard to the Faunal portion of the Table we may say that it only claims to be an approximate record, by no means complete. It is partly the result of collecting during the work of noting the different sections; but much of it is compiled from our knowledge of specimens collected during previous years by ourselves and by other geologists.[1] We are enabled to state more or less approximately the geological date of the species so collected by observation of the character of the matrix; for it may be seen from our sections that the deposits made during different times are easily recognisable by their lithic characters. Cases of doubt of course occur, and such cases are marked by the placing of a note of interrogation before the generic name.

VI. Correlation with Deposits of other Areas.

A knowledge of the Faunal Sequence at Dundry makes it possible to correlate its deposits with similar deposits in other parts of the country, and with those upon the Continent of Europe. In fact, when the hemeral date of any deposit in any locality has been ascertained by a correct

[1] We are indebted not only to those geologists by whose labours the Bristol Museum has been enriched in the past, but also to those who have done so much work at Dundry Hill in the present, Mr. J. W. D. Marshall, Mr. J. W. Tutcher, Mr. A. Vaughan, B.Sc., and other members of the Bristol Geologists' Association, to whom we owe our best thanks for kindly submitting specimens for our examination.

determination of its contained fossils, all that it is necessary to do in correlation is to place it opposite the deposit of another locality of the same date. This we have done in the annexed Table for the strata of Dundry, and of other south-western localities (see Table III. opposite).

VII. Remarks on the Important Features of the Dundry Strata.

Some of the more striking features of the Dundry rocks deserve our attention. We make the following notes :—

1. *The Marlstone Rock.*

The general characters of the rock are :—Coarse, yellowish-brown, ironshot oolite—the oolitic featnre almost universally present, but most strongly developed in the upper portion.

The Marlstone Rock may be seen at Maes Knoll on the western side of the camp, towards the base of the steep escarpment, well within what is marked g5, Inferior Oolite, in the Geological Survey map. It is also well shown in the farmyard by the side of the road at East Dundry ; and here again the line for Inferior Oolite on the Survey map is carried well below its outcrop.

Further, the Marlstone Rock appears on the hillside below Watercress Farm ; and it has been disclosed in field-drains opposite the Rookery. On the northern side of the escarpment from New Down Lane by East Dundry to Maes Knoll, it is shown at various points in the fields, and on the north and west sides of the Knoll. We have also found outcrops of the Marlstone Rock at several other points, but only in that part of the hill which lies to the east of the Chew Stoke road.

In regard to the mapping of the Marlstone as Inferior

Table III.

The Correlation of the Dundry Strata with the Rocks of the Cotteswold and Dorset-Somerset Areas.

Hemeræ.	Cotteswolds.	Dundry.	Dorset-Somerset.	
Zigzag[1]	Limestones above the *Clypeus*-grit.	(?) The strata at Barns Batch. The Coralline-beds.	The *zigzag*-beds of Broad Windsor, Dorset.	
Truellii[1]	The *Clypeus*-grit.	The Dundry Freestone.	The fossil-bed of Halfway House with *Truellii* and *dorsetensis*.	
Garantianæ	The Upper *Trigonia*-grit.	The Conglomerate-bed of Maes Knoll = the thin bed below the Freestone at other places.	The Freestones of Sherborne.	
Niortensis	No Strata.	No Strata.	The upper part of the road-stone of Oborne = Bifurcaten Schichten of Württemburg.	
Humphriesiani	No Strata.	No Strata.	The lower part of the road-stone of Oborne = Coronaten Schichten of Württemburg.	
Sauzei	The *Phillipsiana*-beds of Cleeve Hill.	The Ironshot Oolite of Dundry.	The upper part of the Sandford Lane Fossil-bed.	
Witchelliæ	The *Witchellia*-bed of Cold Comfort and Cleeve Hill, with *Terebratula Wrighti*.	The *Witchellia*-bed—the Upper White Ironshot.	The middle part of the Sandford Lane Fossil-bed.	
	The Notgrove Freestone.			
Sonniniæ	The *Gryphite*-grit of Leckhampton.	The Lower White Ironshot—the *fissilobata-ovalis* horizon.	The lower part of the Sandford Lane Fossil-bed.	
	The *Buckmani*-grit.			
Discitæ	The Lower *Trigonia*-grit.	The upper part of the Grey Limestone and Marl-beds.	The upper part of the Fossil-bed of Bradford Abbas.	
Concavi	The Harford Sands.	The lower part of the Grey Limestone and Marl-beds.	The lower part of the Fossil-bed of Bradford Abbas.	
Bradfordensis	The Upper Freestone.			
	The Oolite Marl.	The hard, irony, massive beds.	The Paving-bed of Bradford Abbas.	
Murchisonæ	The Lower Freestone.			
	The Pea-grit.			
Scissi	The sandy ferruginous beds.		The brachiopoda-beds in the Sand at Stoke Knap; absent at Bradford Abbas.	
Opalini *Aalensis*	The upper part of the Cephalopod-bed.	The bottom beds of stone.	The Freestone of Ham Hill = upper part of Yeovil Sands at Bradford Abbas and Stoford.	
Dumortieriæ	The middle part of the Cephalopod-beds of the Frocester district = the sands of North Stoke (Bath district.)	The Upper Clay-beds—the *Dumortieria*-beds.	The Yeovil Sands = the Blue Clay of Down Cliffs (South Dorset coast), so-called "Upper Lias."	
Dispansi	The lower part of the Cotteswold Cephalopod-bed = the lower part of Midford Sands at Bath.		The Clay below the Yeovil Sands at White Lackington, near Ilminster, so-called "Upper Lias."	
Striatuli	The base of the Cotteswold Cephalopod-bed = the bed below the Midford Sands at Bath.	The Blue Ironshot-beds.		
Variabilis	The upper part of the Cotteswold Sands.		The rest of the so-called "Upper Lias" around Ilminster.	The Junction-bed of the South Dorset coast.
Bifrontis	The lower part of the Cotteswold Sands and the upper part of the underlying clay called "Upper Lias."			
Falciferi	The clay above the Marlstone.	The pink bed.		
Spinati	The Marlstone.	The Marlstone.	The Marlstone.	

[1] These dates, so far as the Cotteswold and Dundry strata are concerned, must be regarded as merely suggestions. The same remark applies to the correlation of the deposits with Dorset.

Oolite it was no doubt the ironshot-oolitic character which deceived the officers of the Geological Survey, as it has doubtless misled geologists subsequently. However, the fossil evidence is clear, and fairly abundant; so too are the number of the exposures about the eastern part of the hill.

2. *The Blue Ironshot-beds.*

The hard deposits lying upon the Marlstone, or separating the upper and lower clays where the Marlstone is absent, we have designated by the above name. At times, however, we have colloquially spoken of them as the "cephalopod-" or "bifrons-beds."

These strata were exposed by excavations at the western end of the hill and at Maes Knoll; and at many other places on the flank of the hill the deposits have been found, recognisable by their peculiar matrix and the contained fossils. At the western end the strata are very thin, but nevertheless give evidence of deposits made during the following hemeræ, *falciferi*, *bifrontis*, *striatuli*, *dispansi*—so that there appears to be wanting any deposit made during the *variabilis* hemera.

At Maes Knoll the beds are thicker. There is here distinct evidence of a deposit laid down during the *variabilis* hemera; and it would seem that during this time the deposit of the *bifrontis* hemera was broken up and again redeposited. Such may also have been the case at the western end of the hill.

The correspondence of this bed or series of beds with those of the Cotteswolds may be seen in our comparative Table III., facing p. 214; but we may note that the deposit separating the beds of the *falciferi* and *striatuli* hemeræ at Maes Knoll is 18 inches only in thickness, partly, no doubt, owing to the breaking-up of the *bifrons*-bed and redeposition, whereas the deposit during the same length of time at Frocester Hill, ascertained by S. S. Buckman by some recent measurements, is as much as 264 feet in thickness.

3. *The Dumortieria-beds.*

It is certainly rather singular that the inappropriate nature of the term "Midford Sands" from a lithological point of view should be shown by a locality so close to Midford as is Dundry Hill. The distance from Midford to Maes Knoll is only $10\frac{1}{2}$ miles; yet the deposit which would be called "Midford Sands" at Dundry is a clay—the "*Dumortieria*-beds"—resting upon a thin ironshot limestone, and this latter deposit is contemporaneous with some 30 feet of the lower portion of "the Sands" at Midford.

With a thickness of some 50 to 60 feet the clays of the *Dumortieria*-bed are to be found all round Dundry Hill, immediately below the limestone series or so-called "Inferior Oolite;" and they may be known by such surface-indications as fruit-trees, springs of water, and so on.

The *Dumortieria*-beds are, in point of date, contemporaneous with the middle portion of the Cotteswold Cephalopod-bed, and, judging by the evidence at North Stoke,[1] near Saltford, with the upper part of the Midford Sands.[2]

[1] North Stoke is 7 miles from Maes Knoll eastward.

[2] The name "Midford Sands" has been applied in a wide sense to certain sandy deposits which were supposed to intervene between what was called Inferior Oolite above and Upper Lias below. But these sands have been shown to be non-contemporaneous, so that the deposit of the same date was called Upper Lias at one locality, Midford Sands at another, and Inferior Oolite at a third. Therefore it is necessary to use the term Midford Sands, in a retricted sense as a local name for certain sandy beds in the neighbourhood of Bath. The other sandy deposits also bear local names for precision. The different dates of these Sands may be seen in our Table III.

4. *The Strata of the Aalenian Age.*

At Dundry there is evidence, in a grey stone at the base of the limestones of the so-called "Inferior Oolite," of a deposit containing ammonites of the *Grammoceras-aalense* type, contemporaneous with the upper part of the Cotteswold Cephalopod-bed.

After this there is evidence of deposition during the *Murchisonæ* hemera, but we have little testimony as to any during the *bradfordensis* hemera; this is partly owing to the want of exposures and partly to the intractable nature of the rock.

5. *The Strata of the Bajocian Age.*

The deposits made at Dundry during the Bajocian Age are noticeable for the large number of ammonites which they yield. Four distinct ammonite faunas may be noted, and the change, even as regards genera in the composition of these faunas, is very marked.

Another point calls for attention, viz., that during this age there evidently was a gradually-increasing supply of iron salts, because the later the deposit the more ironshot is the rock found to be. This character is so noticeable in the deposit of the Sauzei hemera, that that rock has obtained the name of "*the* Ironshot Oolite."

The geographical extent of the Ironshot Oolite is very limited; but that is, in our opinion, on account of events which happened subsequent to its deposition. As to its extension, we may note that it has only been found at the northern and southern roadside quarries, at Rackledown, at East Dundry, and half-a-mile to the east thereof. It is known to be absent from Clements' Yard, Barns Batch Spinney, and Maes Knoll. Therefore in a westerly direction it has been removed entirely in half-a-mile from the main road, and in an easterly direction it probably fails in about three-quarters of a mile east of East Dundry. North and south it is cut off by the escarpment. Consequently the Ironshot Oolite occupies an area in the middle of the hill only, and its extent cannot be more than 1¾ miles long (from east to west) and about one mile wide (from north to south). The reason for the limited east-to-west extension of the Ironshot Oolite is in all probability denudation subsequent to its deposition, to which the flat top of the Ironshot itself bears witness; and the planed-off top of other beds, when the Ironshot Oolite is not present, also tells the same tale.

Above the Ironshot Oolite there is at Dundry a non-sequence; but at Oborne, near Sherborne, are found the deposits laid down in this interval; and these we have noted in our Comparative Table, No. III.

6. *The Strata of the Bathonian Age.*

Of the date of the deposit which follows the stratigraphical gap in the sequence of the Dundry rocks we have a certain amount of evidence from contained fossils: it was laid down during the *Garantianæ* hemera. Therefore it is contemporaneous with the Upper *Trigonia*-grit of the Cotteswolds, which also follows the stratigraphical gap so noticeable in that district; and it is contemporaneous with the Freestones of Sherborne (Dorset).

Of the exact date of the later Dundry deposits we have not much evidence. We have, of course, that of their position in the stratal sequence, and we have the brachiopod evidence of the Coralline beds.

VIII. The Bajocian Denudation.[1]

Nowhere at Dundry Hill is the sequence of Bajocian strata complete; there is, even at the main-road quarries, where deposits have been laid down during the greatest number of hemeræ, a break in their sequence, so that the succeeding bed rests non-sequentially upon the planed-off surface of the Ironshot Oolite.

The portion of the Dundry strata which suffered least from the Bajocian denudation, is that lying between the main road on the west and East Dundry and Rackledown on the east. Westward of this the Bajocian denudation has removed two important fossiliferous beds, namely, the Ironshot Oolite and the *Witchellia*-bed. East of this area there are unfortunately no exposures until Maes Knoll is reached, when the effects of denudation are very striking. The Ironshot Oolite and all the limestone-beds which underlie it have been removed; and further denudation must have taken place there in Bathonian time while deposition was going on quietly at the western end of the hill, for at Maes Knoll there is found a conglomeratic bed of the date of the *Garantianæ* hemera resting upon and containing fossils and rock-fragments derived from beds of the *Dumortieriæ* hemera.

[1] It should be noted that the term "Bajocian denudation" does not mean denudation of rocks of Bajocian age, which might have happened at any date, but a denudation (of any rocks) which was effected during the Bajocian age. In the present case, so far as Dundry is concerned, the denudation doubtless began towards the close of the Bajocian age, and ended at the beginning—before the second hemera—of the Bathonian age. But there is evidence at other places that it continued during the second hemera of the Bathonian age.

IX. Economic Considerations.

1. *The Geographical Extent of the Freestone.*

This is a matter of considerable economic importance. We are able to show that the freestone thins away very rapidly, and also loses the freestone character, as we proceed from Dundry Church to the east—the Northern Main-road quarry—and to the south-east—the Southern Main-road quarry. These beds thin away and deteriorate so rapidly that it is very doubtful whether workable building-stone of good quality would be found a quarter of a mile east of the church. Westward, on Dundry Down, the old workings for freestone are very numerous, occupying a considerable area, and it is probable that nearly all the good stone has been obtained in that direction. There remains, however, the ground east of the Down and south of the church, an area about equal in extent to that which has been worked for stone; and this may certainly be expected to yield freestone of good quality. Farther south, in the direction of Barns Batch, there is a considerable thickness of stone, but its quality would seem to be inferior to that of the Freestone proper. It is obvious, therefore, that the area over which workable freestone is likely to be found is a very restricted one.

2. *The Roadstone.*

Local stone obtained from the Dundry quarries is used for the repair of the roads on the hill. No particular discrimination appears to be exercised in its selection, but nearly all the beds are made to do service. However, the best stone-beds for the purpose are certainly the Ironshot Oolite and the hard, massive beds of Aalenian date. The latter are worked for the purpose at Rackledown, and they were at one time worked to a small extent at the South

Main-road quarry, some five feet below the present floor of that opening. They could be found at many places. Next to these beds, the rubbly coralline deposits furnish a fairly hard stone for road metalling ; so do the thin-bedded equivalents of the Freestone in the roadside quarries and Barns Batch quarry, and the small waste from the upper or inferior bed of freestone in the Freestone quarry.

3. *The Water-bearing Beds of Dundry Hill.*

Springs issue at two principal levels, and occasionally at two or three others, on the upper slopes of Dundry Hill. The chief level for large springs is at the top of the shales of the *Dumortieria*-beds, the water issuing out in streams often of considerable volume and of great persistence at the level where the Aalenian limestones rest upon these impervious argillaceous strata. This is the chief water-bearing bed of the Dundry village: in fact, it is because the *Dumortieria*-beds are clay that the houses of Dundry occupy their present position: had the *Dumortieria*-beds been sands, the water-level would have been nearly fifty feet lower down than it is now.

The level next in importance for springs is the base of the Marlstone Rock, from which water is thrown out at various points along the eastern portion of the northern escarpment and also on the sides of the valley below East Dundry.

At certain points on the western side of the hill, where the Marlstone Rock is absent, or, if present, exists in such a fluctuating and attenuated form as to have hitherto escaped detection, springs occasionally break out from the "*bifrons*-beds": the Elwell spring, south of Castle Farm, is an example. The "Cephalopod-bed," or "*bifrons*-beds," also often gives out small springs on the hillside, both on the northern and the southern escarpment. Small springs also occasionally break out from the grey sandstones in, and especially near the base of, the *Dumortieria* clays; several of the drinking-pools for cattle being thus supplied. Such is the source of the small spring just above the Elwell spring, and of a spring at the old and dismantled Pickwick Farm, west of Maes Knoll; while until recently there was a small spring visible in these beds on the right-hand side of the main road, south of the Butchers' Arms.

Another occasional level for water is the shales with *Terebratula Eudesi*—that is, at about the junction of the strata of Bajocian age with those of Aalenian date—one of these being just below Castle Farm, on the western escarpment.

Some of the smaller springs dry up altogether in the middle of the summer, or in very dry seasons; but the larger springs of Dundry Hill are remarkably persistent.

4. *Suitable Situation for Houses.*

That a deposit of clay should reach nearly to the upper edge of the escarpment round much of Dundry Hill seems to have been a revelation to the inhabitants themselves, who do not necessarily connect a clay with the outburst of springs. But the situation of this clay-bed necessarily delimits the area suitable for the erection of houses when a dry subsoil is a consideration. Questions on this head have been addressed to us by those interested in Dundry as a health-resort, and we should be inclined to answer that the most favourable situation for houses would be about the edge of the line which we have drawn to mark the commencement of deposition in Bathonian time. This should give a dry subsoil, and also water at a reasonable depth. Houses built about this level would not be quite so exposed as those built at higher levels, whilst they would be drier than those built on the lowest beds of the limestone only a little above the level where springs are thrown out by the underlying clays. Of late the tendency has been to build detached farmsteads and cottages on the slopes formed of the Pliensbachian clays, instead of, as of old, on the summit-level of the Hill. Although there are manifest advantages as regards shelter and facility of haulage in these positions over the higher levels, we consider the heavy character of the subsoil and the necessity of trusting to spring water render these sites less suitable from a health standpoint than those indicated by us above the level of the escarpment.

X. The Map of Dundry Hill.

This communication is accompanied by a map, on the scale of 3 inches=1 mile, to indicate the age of the different deposits and their superficial extent as found by us to obtain at Dundry Hill. As the map of the Geological Survey shows round so very much of the hill the Marlstone of the Middle Lias, and even beds below that, coloured as if they were Inferior Oolite, our map is, we consider, of value in that it amends the official document. But we claim that it is of importance in another respect. If the maps of the Geological Survey be taken, and the upper line of the Upper Lias be followed through the counties of Gloucester, Dorset, and Somerset, it will be found to mark a purely physical feature—the place where clay is overlain by sand, which can readily be followed because it is shown by the outburst of springs, and by a change of surface configuration. This method of mapping is based on the assumption that changes of sediment and changes of fauna were practically synchronous; but that assumption has been so often disproved by palæontological research; and it has been shown that even in a short distance, clay passes laterally into sand or limestone. Therefore a map drawn on the stratigraphical method calls the same fossiliferous horizon by different names, in other words assigns to it different dates in different places, to the great confusion of the palæontological student. Such a non-agreement between the palæontological and the stratigraphical methods obtains at Dundry compared with surrounding areas; and therefore the divisions accepted by us in our mapping are based upon purely palæontological lines.

If our method of mapping were extended to other districts the result would be the production of a chronological map based on palæontological evidence,—a map which showed the exact date of the different deposits according to their fossil evidence instead of a map which often shows only where one sedimentary condition ended and another began. Of course, in certain cases a palæontological map would do the same: thus, at Dundry our line marking the commencement of deposition of Aalenian date practically coincides with the upper limit of clay; but if this line were to be extended to the Frocester district of the Cotteswolds it would be some 250 feet above the clay limit. Therefore in digging a well at Dundry the finding of a *Dumortieria* would show that the water level was reached; but the finding of the same fossil in the Frocester district of the Cotteswolds would indicate the hopelessness of trying for water. The geological information would say "go 250 feet lower down."

The divisions which we have accepted are as follows; and in order that they may be compared with the divisions adopted in their maps by the Survey, we place the two side by side.

The present Divisions (chronological, based solely on palæontological evidence).	The Geological Survey Division (stratigraphical).
Bathonian	From the upper portion of Inferior Oolite to the Kellaway Rock inclusive.
Bajocian	Inferior Oolite (*pars*).
Aalenian	Inferior Oolite (*pars*). Midford Sands (*pars*).
Toarcian	Midford Sands (*pars*). Upper Lias.
Pliensbachian . . .	Middle Lias. Upper part of Lower Lias.

As a matter of fact, so far as Dundry is concerned, the line we draw to mark the commencement of deposition in Aalenian time should coincide with the line which the officers of the Geological Survey have drawn as the base of the Inferior Oolite. That there is not always such coincidence is due to an error already alluded to (p. 203). Then the area enclosed by our Bathonian-Aalenian lines represents what would be called "Inferior Oolite, g 5," so far as Dundry Hill is concerned; and the limits which we have laid down may be regarded as = "Inferior Oolite" planned to the best of our ability. Of course only the commencement of the Bathonian [1] age is represented by deposits now at Dundry. The deposits of Bajocian age are so incomplete

[1] It must be remembered that we employ the terms Bajocian, Bathonian, etc., to indicate periods of time Therefore, the term Bathonian is not applied to the Inferior Oolite, but it is given to that portion of time when rocks were deposited which have been called, according to their lithic, not according to their faunal characters, "Inferior Oolite" in some places, "Fullers' Earth" in others. But these divisions of time take no account at all of lithic characters, they are based solely on palæontological phenomena.

and so meagre that we have not attempted to map them separately, and therefore the beds of Bajocian age are, as a matter of fact, marked Aalenian; but their outcrop area is so small that this is not a matter of importance.

Besides the Survey Map there has been a map of Dundry published by William Sanders. From what was said by Mr. H. B. Woodward, F.R.S., at the discussion of our paper,[1] we gather that the Survey map was executed in 1845, and that therefore, so far as Dundry is concerned, it is an earlier document than Sanders' map. That however was not known to us; we could only accept the statement on the map itself, "geological information . . . revised 1867–1871." As Sanders' map was published some years before the earlier of these dates—and it differed seriously from the Survey Map, we supposed that the officers of the Survey had ascertained which map was the more correct.

Mr. H. B. Woodward further says that the differences between our map and the Survey document are small. We thought otherwise—in such cases as hundreds of yards. But the following comparison will show how we differ both from the Survey and from Sanders.

(1) *Comparison of the Geological Survey Map*[2] *with the one here presented.*

The Geological Survey map represents at Dundry only Inferior Oolite resting upon Lower Lias. The boundary-line which we shall have to notice is that drawn separating the deposits so classed. Beginning at the main road on the north flank of the hill, and going westward, the Survey's

[1] *Quarterly Journal Geological Soc.*, vol. 52, p. 720.

[2] Sheet XIX. 'Geological Information revised, and Penarth Beds surveyed, by H. W. Bristow, H. B. Woodward, W. A. E. Ussher, and J. H. Blake, 1867–1871. New edition. Published May, 1873.'

boundary-line of Inferior Oolite coincides with our own (beginning of deposition in Aalenian age), and is drawn at the top of the *Dumortieriæ* clays, along by the village and by "the Grove," until about 250 yards north of Castle Farm, when it strikes off to the top of the "Cephalopod-" or "*bifrons*-beds"; and at Castle Farm it is about 150 yards outside our line. It continues on or a little below this horizon round the southern flank of the hill to Rackledown Farm, when it drops below the Marlstone—as much below, in fact, as it ought to be if the Marlstone were really the Ironshot Oolite of the *Sauzei* hemera. It continues at this level round both sides of the East Dundry Vale, with the result that the Survey's base-line of Inferior Oolite is, at the head of the valley, as much as 650 yards outside ours.

Their boundary-line then continues to run on this infra-Marlstone level to Maes Knoll, where in drawing our line we differ from the Survey to the extent of about 100 feet in vertical thickness, and in some places, as at the north-eastern corner, to the extent of about 250 yards in horizontal distance.

From Maes Knoll their boundary-line continues along the northern flank of the hill on the infra-Marlstone level until it approaches the main road whence we started, when they show a lengthy northward prolongation of "Inferior Oolite" by the eastern side of the bend in the main road. This projection is not only some 400 yards outside the boundary of what they call Inferior Oolite on the other side of the road, but it is even some 250 yards outside what we take to be the horizon of the Marlstone.

It will thus be seen that, except along the northern flank of Dundry Hill, to the west of the main road, the Survey have mapped far too great an area as Inferior Oolite, and as a consequence have given far too great a vertical thickness to the "Inferior Oolite." The latter result of course obtains more at Maes Knoll than elsewhere, because there only a very thin capping of strata of Bathonian age is left to represent the "Inferior Oolite."

(2) *Comparison of Sanders' Map*[1] *with our own.*

Commencing at the main road, as before, Sanders shows the base of the Inferior Oolite at the top of the Marlstone; then going west the line rises, and is carried along about the middle of the *Dumortieria*-beds all round the hill until it meets the main road at the south, by Elton Farm, when it drops to the Marlstone level. Thence it is carried at this horizon until a little east of Watercress Farm, on the southern flank of the East Dundry Vale. Here it begins to rise gradually, and at the head of the valley, at the Butchers' Arms, it reaches the top of the *Dumortieria*-beds, so that here it coincides with our own map and differs seriously from that of the Survey. Returning, on the north flank of this valley, it drops to the Marlstone level just before East Dundry is reached, and along that horizon it is continued until above Northwick Cottages. Here Sanders' Inferior-Oolite line makes a large outward bend, as much as 500 yards outside our Marlstone limit. Then it returns to the Marlstone limit, at about the middle of the bend before reaching Maes Knoll, and is carried at about this level round the hill until the main road on the northern flank is again reached. It does not show that great bend at this point which is so conspicuous on the Survey map.

[1] Sanders, William: 'Coalfields of Bristol and the Country adjacent geologically surveyed.' Folio manuscript, 1862. Map published on the scale of 4 inches to 1 mile; republished by Lavars & Co., Bristol, on the scale of 1 inch to 1 mile.

It will be seen, therefore, that Sanders' map approximates more closely to our own than does that of the Geological Survey, and that for the western portion of the hill it is generally only a little outside our "Inferior Oolite" limit. For the eastern portion of the hill there are considerable differences between our map and his, which, like the Survey map, shows far too great an area as "Inferior Oolite"

XI. Conclusion.

Although this account of the geological structure of the upper portion of Dundry Hill is somewhat full of detail, we should like to take this opportunity of impressing on the geologists who have the opportunity to examine Dundry rocks the large field which still lies open to them. For instance, the definite collection of fossils *in situ*, so as to fix exactly the date of their existence, and thereby supplement as well as check the faunal lists which we have given, is a very necessary piece of work. It will have important bearings on phylogenetic questions, which demand so much consideration in palæontology; and it will influence the determination as to the value of certain forms as species or otherwise. Much information is needed concerning the rocks of Aalenian date, particularly as to strata contemporaneous with the hard massive beds at Rackledown, which we have dated as belonging to the *Murchisonæ*, and perhaps in part to the *bradfordensis* hemeræ. Then there is the question as to the strata exposed at Barns Batch on the south-western side of the hill, and as to what is their connection with the other upper beds of Dundry: are they contemporaneous with the Freestone and Coralline, or are they of later date?

Further, there is the question of the exact limits of the easterly extension of the strata of Aalenian and Bajocian date, and in fact the structure of that part of the hill between East Dundry and Maes Knoll of which we are at present quite ignorant, requires to be worked out in detail.

One point more we may notice with regard to the palæontology; there is a very large field for work here for any one living in the neighbourhood of Dundry. The number of species found at Dundry which have never been described or figured is a very large one, although from the nature of their exposures several beds have been most inadequately explored. As with successive visits to the Dundry sections new finds are constantly being made, it may be confidently asserted that many new forms yet remain to be discovered.

XII. Summary.

In this paper we give information on the following points:—

1. The general structure of the upper part of Dundry Hill.

2. The faunal sequence.

3. A time-table of the deposits at Dundry, the Cotteswolds, and the Dorset-Somerset area.

4. Economical details, concerning the Freestone, the Roadstone, the Water-bearing beds, and Sites for Houses.

5. A map of the Hill. This map shows the extent of the deposits of different dates, and, together with the diagram, it illustrates the facts—

(*a*) That strata equivalent to what are called elsewhere Midford Sands, Upper Lias, and Middle Lias (Marlstone) are present in the hill, the two former attaining a maximum thickness of more than 60 feet, whilst the Marlstone outcrops at many points along the flanks of the range.

(*b*) That the officers of the Geological Survey have apparently confounded the Marlstone Rock (an ironshot oolite of the date of the *spinati* hemeræ) with the well-known Ironshot Oolite (of the date of the *Sauzei* hemeræ), a bed nearly 100 feet higher up.

(*c*) That in consequence of this mistake they have, round the greater part of the hill, drawn the base of the Inferior Oolite as far below the Marlstone as this base ought to have been drawn if the Marlstone were really the Ironshot Oolite or *Sauzei*-bed.

(*d*) That the Survey have mapped as Inferior Oolite strata which are marked by them elsewhere as Lower Lias, Middle Lias, Upper Lias, and Midford Sands.

(*e*) That the superficial extent of the Inferior Oolite has been greatly exaggerated on all previous maps.

6. That at Dundry Hill the sequence of strata laid down during Bajocian-Bathonian ages is incomplete, because there is no deposit to represent the time of the *niortensis* or *Humphriesiani* hemeræ; in fact, presumably, during these hemeræ denudation was in progress at Dundry.

7. That all the strata of the Aalenian and Bajocian ages have been removed from the eastern end of the hill, so that strata of Bathonian date (*Garantianæ* hemera) rest non-sequentially upon deposits laid down during the *Dumortieriæ* hemera.

8. That this removal has been effected by denudation in Bajocian and even post-Bajocian time.

Postscript.—In this paper we have substituted the term Pliensbachian for Charmouthian, which was used by us in our communication to the Geological Society. Mr. H. B. Woodward, F.R.S., has kindly given us the following information:—"In the last volume published by the Internat. Geol. Congress (Zurich) there is appended a Table of Strata by Renevier. He adopts the term Pliensbachian of Oppel, 1858,[1] for both Liasian and Charmouthian—these two being put as synonyms." As Pliensbachian was proposed some years before the term Charmouthian, suggested by Mayer-Eymar in 1864, it has the right of priority; and we only do justice in acknowledging that right. Oppel's objection to d'Orbigny's prior term Liasien, that it is really applicable to the whole of the Lias and not to a part, is justifiable, quite warranting his proposal of a new term Pliensbachian.

[1] Juraformation, p. 815: "Pliensbach, a village near Boll in the Swabian Alps."

Notes on the British Jurassic Brachiopoda.

PART II.[1]

By J. W. D. MARSHALL.

TEREBRATULA, Klein, 1753.

Etym.—Diminutive of *terebratus*, perforated.

ANIMAL fixed by means of a peduncle passing through an ovate or circular foramen, situated at or near the extremity of the beak of the ventral valve; foramen partly or entirely margined by one or two triangular plates constituting the deltidium. Valves articulated. Labial appendages supported by the crura or basal portion of the calcareous loop. The loop is very simple in design, short, and is attached to the hinge-plate of the dorsal valve in the posterior portion of the shell. There is no median septum as in *Waldheimia* of King. The shell structure is always punctated.

It is very difficult in a few words to accurately describe the shape of the shell, there being so much variation in the different species; some are almost spherical, others more or less ovate, transverse or elongated.

[1] The First Part was published in Vol. VIII., Part 1 (1895–1896).

Terebratula proper is first met with in the Jurassic rocks, but was represented in the Devonian, Carboniferous and Permian, by a near ally, *Dielasma*. It is represented in existing seas by another close ally, *Liothyrina*, of which eight to ten species are known.

Excluding three unnamed shells, Davidson figured and described in his Jurassic Monograph fifty-three species, three doubtful species, and fifteen varieties of *Terebratula* from the Lias and Oolites of this country. The following species, all of which belong to other genera, must, however, be deducted from that number :—*Ter.* (?) *flabellum*, *hemisphærica*, *perieri*, *suessi*, *hybrida*, *morierei*, *coarctata*, and var. *reticulata*, *bentleyi*, *curviconcha*, *curvifrons*, *galeiformis*, *provincialis*, *boloniensis*, and *gesneri*.

It is interesting to note that only four species and three varieties are recorded for the Lias, while of the remainder no less than twenty-seven species and nine varieties are from the Inferior Oolite.

Very few additional species have been made since Davidson's death. The following are the only ones that have come under my notice :—[1]

Ter. pisolithica, S.S.B., Inferior Oolites of the Cotteswolds (2).
,, *notgroviensis*, S.S.B., ,, ,, ,, ,, ,, (2).
,, *euides*, S.S.B., ,, ,, ,, Dorset.[2]
,, *decipiens*, var. *chadwicki*, W. and B., Dogger of the Peak, Yorkshire (18).

Mr. Walker has also identified the two following species: *Ter. repeliniana*, d'Orb., found by Mr. S. Chadwick in the Coral-rag of Helmsley, Yorkshire (18), and *Ter. ovatissima*, Quenst., found in the Lower Lias of Radstock. There exist

[1] *Vide* Appendix.
[2] *Geol. Mag.*, Dec. III., Vol. III. (1886), p. 218.

however, a very large number of forms to which as yet names have not been given, and others which have manuscript names, but have not yet been figured or described by their authors. This applies to other genera and species of Jurassic Brachiopoda, many of which are in my collection.

One important feature in connection with the Terebratulæ is that they can conveniently be arranged in groups, such as fimbria, maxillata, punctata, sphæroidalis, etc.; in fact, it is often much easier to place them in such groups than to distinguish between the species, some of which are so closely allied that it is almost a matter of impossibility to separate them. In this respect the same may be said of the Rhynchonellæ, and of the so-called Waldheimiæ.

Some species were very prolific—*Ter. punctata*, and its varieties, from the Lias, and *Ter. globata*, *fimbria*, *maxillata*, and *intermedia* from the Oolites; on the other hand, *Ter. jauberti* and *walfordi* from the Lias, and *Ter. craneæ*, *tawneyi*, and *euides*, from the Oolites, are unquestionably among the rarest forms.

This is undoubtedly a good centre to radiate from in search of Terebratulæ, and it may also be said of Rhynchonellæ and other brachiopods. Around our city the Lias and Oolites are well developed, and many species may be collected. In the Somerset-Dorset area the larger percentage of species have been found. Again, in close proximity to us are the Cotteswold Hills, where another large and interesting series have been obtained.

Types of the following species may be seen in the Bath Museum:—

Ter. punctata, var. *edwardsii*, Dav., from the Middle Lias of Ilminster.

Ter. punctata, var. *subpunctata*, Dav., from the Middle Lias of South Petherton.

Also a described specimen of *Ter. perovalis*, Sow., from the Inferior Oolite of Dinnington (23).

The type of *Ter. etheridgei*, Dav., from the Inferior Oolite of Dundry, is located in our Museum, also of *Ter. punctata*, var. *radstockensis*, Dav., from the Lias of Radstock (22). The types of *Ter. eudesi*, Oppel, and *tawneyi*, Whid., were found in the Inferior Oolite of Dundry; *Ter. eudesi* is abundant in the *concavum*-beds of that place, especially at the western end of the hill.

DICTYOTHYRIS, Douvillé, 1879.

Etym.—δίκτυον, a net; θυρίς, a small opening.

The shells familiarly known to us as *Terebratula hybrida* and *morierei*, from the Inferior Oolite of Dorset; *Ter. coarctata*, from the Great Oolite and Bradford-clay in the neighbourhood of Bath; *Ter. coarctata*, var. *reticulata*, from the Fuller's Earth, near Frome; and *Ter. bentleyi*, from the Cornbrash of Stilton, near Peterborough, are the Jurassic forms which belong to Douvillé's *Dictyothyris*. With the exception of *Dicty. bentleyi*, they may be recognised by the beautiful reticulated appearance of the surface of the valves, formed by the longitudinally raised striæ intersected by transverse lines.

Dictyothyris is characterized by a mode of plication of its valves, the opposite to what obtains in the "*Biplicatæ*" (*Terebratula*) of Douvillé (13). Davidson, however, did not consider this to be of sufficient importance to warrant the separation of these shells from *Terebratula*, in which genus he placed them. Œhlert makes *Dictyothyris* a subgenus of *Terebratula*.

With the exception of *Dicty. coarctata*, all the species of *Dictyothyris* are rare, *Dicty. hybrida* especially so.

GLOSSOTHYRIS, Douvillé, 1879.

Etym.—γλώσση, a tongue; θυρίς, a small opening.

One of the distinguishing features in *Glossothyris* is the pronounced sulcus in the imperforate or dorsal valve.

Davidson objected to this genus on the ground that it seemed to him to be based upon very deceptive external characters. He considered it a synonym of *Terebratula*, and therefore included *Glossothyris curviconcha* from the Inferior Oolite of Dorset, and *Glos. bakeriæ*,[1] from the Middle Lias of Northants in that genus, species which, according to Douvillé and some other authors, are generically distinct.

Glos. (?) *curvifrons*, *galeiformis*, and *provincialis*, all from the Inferior Oolite, are species closely allied to *Glossothyris*; they certainly do not belong to the *Terebratula* of Douvillé (13). It may be mentioned that Œhlert makes *Glossothyris* a section of his *Terebratula*, and not a distinct genus (16, p. 1316).

The above species, with the exception of *Glos.* (?) *curvifrons*, are very rare.

WALDHEIMIA, King, 1850, *et auctorum.*

Etym.—Dedicated to Fischer de Waldheim, naturalist.

Prior to 1850, all the species to which we now give the familiar generic title *Waldheimia* were included in *Terebratula*, although it was generally known that the former possessed a mesial septum and a long loop, while the latter had a short loop and no mesial septum. Professor William King, to whom we are indebted for several well-known genera of Brachiopods, recognised the necessity of making two groups of these Terebratuloids, and proposed the term *Waldheimia* for the former. He gave a diagnosis of the

[1] Figured by Davidson as *Wald. bakeriæ.*

genus in his "Monograph of the Permian Fossils of England," published in the year 1850, dedicating it to a distinguished Russian palæontologist, Fischer de Waldheim (14, p. 145).

However, the name did not come much into use in this country until after the publication of Thomas Davidson's "Introduction to the Study of the Brachiopoda" (8). This, perhaps, is not to be wondered at, seeing that only a short time previously Davidson did not altogether approve of the generic separation of *Waldheimia* from *Terebratula*, as may be gathered from the following remarks: "The greater or less length of a simply attached loop in *Terebratula* cannot be made use of as a generic character, especially when there exists no other distinctive points. The length of the loop may be used as sectional, round which we can group certain species; but who, with any degree of confidence, would place in distinct genera such shells as *Ter. cornuta*, *quadrifida*, *numismalis*, *obovata*, *digona*, *ornithocephala*, etc., which have a simply-attached loop extending to near the frontal margin of the valve, and those such as *Ter. punctata*, *perovalis*, *maxillata*, *intermedia*, *sphæroidalis*, *coarctata*, etc., the loop of which, simply attached to the crura, only extends to less than half the length of the valve?" (7, p. 4).

Later on Davidson withdrew his objection, and considered that the term *Waldheimia* might be advantageously preserved for those species possessing a long loop. In the latter portion of his monograph he frequently refers to the well-established genus *Waldheimia*, King.

In 1884 Davidson issued his "General Summary to the Brachiopoda," wherein he reviewed the work he and others had accomplished since the year 1850, and in this work he gives his latest classification of the Brachiopoda, so far as the fossil forms are concerned. He placed King's genus *Waldheimia* in his (Davidson's) sub-family Terebratulidæ.

Further, he not only gave particulars of his own system of classification, but also—only rather too cursorily—of the classification adopted by some of the chief Continental authorities, one of which, M. H. Douvillé's, is especially interesting.

In 1879 Douvillé divided the species included in King's *Waldheimia* into seven genera, placing them in a distinct family named Waldheimiidæ (13, p. 251). The genera are as follows :—

I. *Macandrevia.*
II. *Waldheimia.*
III. *Neothyris.*
IV. *Plesiothyris.*
V. *Zeilleria.*
VI. *Eudesia.*
VII. *Aulacothyris.*

This sub-division of the genus *Waldheimia* was based largely upon the presence or absence of rostral septa, and the mode of the plication of the valves. Davidson not only questioned the propriety or necessity of establishing a second family, or even sub-family Waldheimiidæ, but also objected to Douvillé's so-termed genera, considering them as only synonyms of King's genus *Waldheimia.* In opposition, however, to Davidson's opinion, Douvillé's classification was generally adopted among brachiopodists in this country and on the Continent, so that the generic names *Plesiothyris*, *Zeilleria*, *Eudesia*, and *Aulacothyris*, applied to our Jurassic *Waldheimiæ*, are now familiar terms.

In the same year as the "General Summary" was issued, Dr. Davidson passed away from the scene of his labours, not, however, before he had prepared some excellent notes, which, under the careful editorship of Miss Agnes Crane, culminated in his posthumous "Monograph of the Recent Brachiopoda" (11).

In a footnote on page 40 of this valuable work reference is made to the fact that Professor J. Hall, of America, and Eug. Deslongchamps, of France, question whether the term *Waldheimia* could be retained, as the name had been given by Brullé, in 1846, to a genus of hymenopterous insects.

So far as I am aware this is the first intimation by Davidson to the effect that any alteration of the name *Waldheimia* would be necessary, which is strange, because Bayle, six years previously, had proposed the name *Magellania* for the shells under consideration.

This term, *Magellania*, is now generally in use among those who study the brachiopoda, and as Miss Agnes Crane says: "The substitute possesses the unusual merits of commemorating the exploits of a celebrated navigator, and of indicating at the same time the region of the maximum development of the genus it distinguishes; for the Magellanian province, as Darwin first pointed out, is remarkable for the great size of the mollusca inhabiting it, and to this rule the Brachiopoda form no exception" (*Natural Science*, Vol. II., No. 11, January, 1893).

During the time Davidson was engaged in the compilation of his Monograph, a period extending over thirty-four years, Quenstedt, Douvillé, Deslongchamps, Bayle, Zittel, and many other distinguished palæontologists were at work in their respective countries in elucidating the life-history of the Brachiopoda, but it is unnecessary to review their work in detail. However, a few words may be said concerning the classification of the Terebratulidæ as proposed by Eug. Deslongchamps in 1884 (12, p. 292).

This author altogether ignored the greater or less length of the brachial apparatus, considering it as a most artificial character and of no generic importance.

He divided the Terebratulidæ into two groups: the first in which there is no metamorphosis of the loop during life, and where the mantle is furnished with calcareous spicules; in this group he placed the following genera, *Liothyrina*, *Terebratulina*, *Megerlea*, *Kraussina*, and *Platidia*. In the second group the mantle is not furnished with spicules, but the loop undergoes a metamorphosis, or passes through various stages, such as the *Platidiform*, *Magadiform*, *Mühlfeldtiform*, *Terebratelliform*, etc.; in this group he placed *Terebratula*, *Waldheimia* (*Magellania*), etc.

The classification of the Magellaniæ as proposed by D. P. Œhlert of France, may now be considered (16, p. 1317). After giving a few general generic characters of *Magellania*, this author divides it into two sections, viz., *Magellania*, *sensu stricto*:—Surface plicated (Type: *M. flavescens*, Lam. sp.); and *Neothyris*, Douvillé, 1879:—Valves smooth, non-plicated; commissure rectilinear (Type: *N. lenticularis*, Desh. sp.). Then quite aside of these two sections he divides the genus *Magellania* (in the wide sense, which is equivalent to *Waldheimia*, King), into two sub-genera—*Eudesia* and *Macandrevia*—and then proceeds to subdivide *Eudesia* (which he uses in a much more comprehensive sense than King did, and which he, Œhlert, considers is equal to the *Orthotoma* of Quenstedt, 1871) into a number of sections, as follows:—

I. *Eudesia*, *sensu stricto*. (*Flabellothyris*, Eug. Deslongchamps, 1884.) (Type: *E. cardium*, Lam. sp.)

II. *Zeilleria*, Bayle, 1878. (Type: *Z. cornuta*, Sow. sp.)

III. *Fimbriothyris*, Eug. Desl., 1884. (Type: *F. guerangeri*, Desl. sp.)

IV. *Ornithella*, Eug. Desl., 1884. (Type: *O. indentata*, Sow. sp.)

V. *Microthyris*, Eug. Desl., 1884. (Type: *M. lagenalis*, Schl. sp.)

VI. *Aulacothyris*, Douvillé, 1879. (Type: *A. resupinata*, Sow. sp.)

VII. *Epicyrta*, Eug. Desl., 1884. (Type: *E. eugenii*, Von Buch sp.)

VIII. *Cincta*, Quenstedt, 1871. (Type: *C. cor*, Lam. sp.)

IX. *Plesiothyris*, Douvillé, 1879. (Type: *P. verneuilli*, Desl. sp.)

X. *Antiptychina*, Zittel, 1883. (Type: *A. bivallata*, Desl. sp.)

XI. *Orthoidea*, Friren, 1875. (Probably young of *numismalis*.) (Type: *O. liasina*, Friren sp.)

This arrangement does not appear very satisfactory. In a future communication I hope to state my reasons for thinking so. However, as some seven or eight of these sections are met with in our Jurassic rocks, we may now proceed to a consideration of them.

Eudesia, *sensu stricto*.

(Type: *E. cardium*, Lam. sp.)

Etym.—Dedicated to M. Eudes Deslongchamps, the distinguished palæontologist.

Eudesia was briefly described by King, its author, as "A plaited *Terebratulidia*. Marginal outline more or less oblong longitudinally. Beak projecting; truncated by a large foramen, which is bounded inferiorly by a deltidium. Punctures moderate in size. Type: *Ter. orbicularis* = *Ter. cardium*, Lam. sp." (14, p. 144). This brief diagnosis is not exceeded by Deslongchamps. He simply states that "*Eudesia* is characterized by the angular disposition of the plicæ, by the relatively compressed form of the beak, and by the narrow cardinal line even in the young state" (12, p. 261). *Eudesia* is represented in this country by one species only, the type, *E. cardium*, which may be found in the Great Oolite, and Bradford-clay, of Bath, Box, Bradford-on-Avon, and neighbourhood. There is a so-called variety, *leckhamptonensis*, Walker, from the Inferior Oolite of Leckhampton Hill, Glos., which is a very rare shell indeed.

FLABELLOTHYRIS, Eug. Deslongchamps, 1884.

(Type: *F. flabellum*, Defrance sp.)

Etym.—*Flabellum*, a small fan; *θυρίς*, a small opening.

Deslongchamps divided *Eudesia* into two sections, *A* and *B*: in the former he placed *Eudesia* (*Ter.*) *cardium*; in the latter, *Flabellothyris* (*Ter.*) *flabellum*. This author says, "*Flabellothyris* may be distinguished from *Eudesia* by its more rounded form and often greater nodulosity of its plicæ, which are coarser and fewer in number; and by its nearly transverse shape . . . The best known form is *Ter. flabellum*, Defrance sp. . . . This section presents a well-marked transition from *Eudesia* to *Ismenia*" (12, p. 261).

This being so, we may for the present retain the term *Flabellothyris*. If Davidson's figure of the loop of *F. flabellum* be correct, then *Flabellothyris* ought to be placed with the short-looped Terebratuloids. (7, p. 62, Pl. xii. fig. 21.)

Flabellothyris is represented in the Jurassic rocks of this country by one species only, the type, a very rare and beautiful shell; it is found in the Bradford-clay, at Bradford-on-Avon, Wilts.

ZEILLERIA, Bayle, 1878. (Type: *Z. cornuta*, Sow. sp.)

Etym.—Dedicated to Zeiller, naturalist.

The generic appellation of *Zeilleria* was adopted by

Douvillé, Deslongchamps, and others; but was rejected by Davidson, whilst Œhlert makes it a section of his *Magellania*.

Deslongchamps divided his *Zeilleria* into one sub-genus, *Meganteris*, Suess, which is represented in the Silurian and Carboniferous deposits, and 13 sections, of which six are named; the other sections are represented by letters only, *A*, *B*, *C*, etc.

It should be borne in mind that Deslongchamps expressly stated that he did not consider his groups of the *Zeilleriæ* as being of generic value.

Not having had access to Bayle's diagnosis of his *Zeilleria*, and in the absence of a diagnosis by Œhlert of his section *Zeilleria*, it is necessary to quote Deslongchamps, who in his section *A* describes the special group to which *Z. cornuta*, the type of Bayle's genus *Zeilleria*, belongs. His description is as follows: "This section is characterized by a very strongly carinated beak, small foramen, shell slightly swollen, with the frontal region bilobed or quadrilobed. Met with chiefly in the Lias." Examples:—*Z. quadrifida*, Lam. sp., *Z. cornuta*, Sow. sp. (12, p. 271).

Splendid specimens of the above have been met with in the Ilminster and South Petherton district.

If Œhlert be followed, it would appear to be necessary to retain in this section, for the present, a large number of our Jurassic species, such as *subnumismalis*, *lycetti*, *perforata*, *digona*, *obovata* and its varieties, *vicinalis*, etc., etc.,

ORNITHELLA, Eug. Deslongchamps, 1884.

(Type: *O. indentata*, Sow. sp.)

Etym.—Diminutive of ὄρνις, a bird.

In this section the beak is recurved, and slightly carinated. Foramen small or very small. Form elongated, globose;

without projecting part at the periphery; front round, square ended or slightly bilobed (12, p. 273).

This section is represented in the Middle Lias of the Ilminster district by *O. indentata*, Sow.; in the Fuller's Earth of the Sherborne district by *O. cadomensis*, E. Desl.; in the Cotteswolds by *O. hughesi*, Walker; in the Fuller's Earth of the Bath district by *O. ornithocephala*, Sow.; and in the Middle Oolites by *O. umbonella*, Lam., and *O. bucculenta*, Dav.

Deslongchamps made *Ornithella*, like *Microthyris*, *Aulacothyris*, and *Cincta*, sections of his genus *Zeilleria*.

MICROTHYRIS, Eug. Deslongchamps, 1884.

(Type: *M. lagenalis*, Schl. sp.)

Etym.—μικρός, small; θυρίς, a small opening.

In this section the beak is very much recurved in the form of a crook, which is finely pointed, without lateral carinæ, and pierced with a foramen of small dimensions. The form is elongated, swollen at the umbones, depressed and sharply truncated at the front (12, p. 274).

Deslongchamps said that *Microthyris* is one of the best characterized groups of the *Zeilleriæ*; and that it is composed of only a single species, the *Ter. lagenalis* (Schl.), which is confined to the Cornbrash.

Fine examples of this species, and a so-called variety *sub-lagenalis*, Dav., are found in the Cornbrash of Gloucestershire and Oxfordshire.

AULACOTHYRIS, Douvillé, 1879.

(Type: *A. resupinata*, Sow. sp.)

Etym.—αὖλαξ, a furrow; θυρίς, a small opening.

The shells in this section can easily be distinguished from those of the preceding sections by the presence of a well-defined median sinus in the dorsal valve, which depresses in front the commissure of the valves.

The beak, which is generally perforated by a small and oblong foramen, is slender, strongly carinated, and hollowed out on the sides. The form of the shell is more or less elongated (13, p. 277).

Aulacothyris is met with chiefly in the Middle Lias and Inferior Oolite. In the latter division it is well represented by *A. carinata*, Lam., and its numerous varieties. At Dundry *A. carinata* is rare, although it is usually found fairly plentifully elsewhere, in fact, wherever the upper beds of the Inferior Oolite are exposed in this neighbourhood.

The Middle Lias of the Ilminster district has yielded excellent examples of the type species.

It should be borne in mind that *Aulacothyris* is only a stage of development giving rise to forms without the furrow, which are called *Zeilleria*. The young of *leckenbyi*, *anglica*, etc., are often furrowed. Old forms of *carinata* are not always furrowed, although they are more or less so in the young state.

CINCTA, Quenstedt, 1871. (Type : *C. cor*, Lam. sp.)

Etym.—*cinctus*, a girdle.

Beak small, acuminated and pointed, very strongly carinated; foramen excessively small. Shell broad, sometimes transverse, greatly depressed although convex in both valves; frontal region sharply truncated. This group is only met with in the Lias (12, p. 275).

The above diagnosis of *Cincta* is given by Deslongchamps. Œhlert does not give any diagnosis; he simply quotes it as a section of his sub-genus *Eudesia* under the genus *Magellania*. Quenstedt divided the Brachiopoda into several groups.

The *Waldheimiæ*, as we understand it, he divided into two groups, the *Epithyridæ cinctæ* and the *Epithyridæ impressæ*. The latter group correspond with Douvillé's *Aulacothyris*, *i.e.*, comprise *A.carinata*, *resupinata*, etc.; while the *Epithyridæ cinctæ* is a most comprehensive group, as it includes such diverse shells as *Eudesia cardium*: *Zeilleria quadrifida* and *cornuta*; *Zeilleria vicinalis*, *digona*, *obovata*, etc.; *Ornithella indentata* and *bucculenta*; *Microthyris lagenalis*; *Cincta numismalis*; *Terebratula punctata*, *ovatissima*, etc. (17). Quenstedt evidently used his terms in a collective and not generic sense, as may be gathered from the fact that he included in his *Cinctæ*. *Terebratula* as well as *Waldheimia*.

Excellent specimens of *C. numismalis* are to be found in the Jamesoni-beds at Radstock; also of *C. cor* in the Bucklandi-beds (?) of the same district.

Plesiothyris, Douvillé, 1879.

(Type: *P. vernueilli*, Desl. sp.)

Etym.—πλησίος, near; θυρίς, a small opening.

According to Douvillé the species of *Plesiothyris* are few in number, and represent aberrant forms. Although the apophysary system of the type species is but very imperfectly known, yet it is generally supposed to be long and characteristic of the *Waldheimiæ*. The beak is small and bears on each side a prominent ridge, bounding a well-marked area. Dorsal valve doubly folded. Form elongate (13, p. 275).

Deslongchamps, with some doubt, made *Plesiothyris* a section of Zittel's *Antiptychina*.

Plesiothyris is extremely rare in our Jurassic rocks, the only species I know being *Plesiothyris reversa*, and *brodiei*, from the Inferior Oolite of Louse Hill, Dorset.

ORTHOIDEA, Friren, 1875. (Type: *O. liasina* Friren sp.)

Etym.—*ὀρθός*, straight; *εἶδος*, like.

I have not seen any literature relating to Friren's *Orthoidea* other than Œhlert's, who considers that it is perhaps based only on a young form of *numismalis*.

This concludes the examination of the sections of *Magellania* found in our country, as proposed by Œhlert. Space will not permit of our entering into a fuller criticism of his classification; this must be postponed for another communication.

Since 1877 a very large amount of work has been done in America and elsewhere in re-classifying the Brachiopoda as a class, so much so that everything is thrown into apparent confusion at present. However, we must not be discouraged because an advance in our knowledge of the evolution of the Brachiopoda necessitates the altering and re-labelling of our specimens.

A word or two respecting the distribution of the *Magellania* in the Jurassic rocks.

Davidson figured and described in his Monograph forty-two species and thirteen varieties of *Magellania* (*Wald.*) as occurring in the Oolitic and Liassic rocks of this country. In this number he included *Zeil.* (?) *humeralis*, Roemer, *Glossothyris bakeriæ*, Dav., and an unnamed shell.

The genus is represented in existing seas by some ten or eleven species.

The following species have been added since Davidson's death:—[1]

Zeil. rudleri, Walker and Buckman, Passage beds of the Lower Calc.-grit of Suffield Heights, near Scarborough.

[1] *Vide* Appendix.

Z. witchelli, S. Buckman, Inferior Oolite, Notgrove Station, Glos.

Z. strangwaysi, Walker and Buckman, Dogger of Peak, Yorkshire coast.

Z. vicinalis, Quenst., Lower Lias, Radstock, has been identified by Mr. Walker (2, p. 18).

Aul. bernardina, Oppel, has been identified by Mr. Walker from the Oxford Clay of Huntingdonshire. (*York. Phil. Soc. Report* for 1884.)

The type specimen of *Z. subnumismalis*, Dav., and a described specimen of *Z. quadrifida*, Sow., both from the middle Lias of Ilminster, are located in the Bath Museum (23).

Described specimens of *Z. anglica*, Oppel, are in our Museum (22).

TEREBRATELLA, D'Orbigny, 1847.

Etym.—Diminutive of *Terebratula*.

Davidson describes the shell of *Terebratella* as elongated or transverse, and variable in shape: both valves regularly and unequally convex or interrupted by a longitudinal depression in the smaller valve. Beak truncated by an oblique foramen of a circular or oval form, and partly margined by a deltidium in two pieces, at times disunited above the umbo: beak-ridges more or less well-defined, and in some cases bearing between them and the hinge-line a flat or concave cardinal area. Valves articulated: external surface smooth or variously punctated. In the interior of the dorsal valve, under the cardinal process and hinge-plate, is developed a more or less elevated medio-longitudinal crest or septum which extends to about half the length of the valve. The loop is elongated and doubly attached, first to the hinge-plate, and afterwards to the mesial septum, by processes given off at right angles near the centre of the valve, the remaining portion soon after becoming reflected (8, p. 65).

Terebratella first made its appearance in the Oolitic rocks, where it is represented by the following species :—

T. buckmani, Moore (type in the Bath Museum), *T. furcata*, Sow., and *T. moorei*, Dav., all three from the Great Oolite of Hampton Cliff, near Bath.

A *Terebratella*-like shell is found in the Middle Lias; it is provisionally placed in this genus as *T.* (?) *liasiana*, Desl. sp.

Terebratella is represented in existing seas by some nine to twelve or more species. Whether or not the researches made by Messrs. Œhlert and Fischer on the recent Brachiopoda of the Magellanian province will bring about an alteration in the generic appellation of our Jurassic *Terebratellæ* it is difficult to say at present. They certainly have demonstrated beyond the possibility of a doubt that the genera *Waltonia* (Davidson), and *Magasella* (Dall), are really immature *Terebratellæ* in which the brachial apparatus has not completed its development; also that *Terebratella* is closely related to and should precede *Magellania* in any system of classification based on the natural evolution of genera (6).

It is only right to say that Davidson was not satisfied that *Magasella* was a good genus; he thought that the species so referred were perhaps undeveloped forms of *Terebratella*.

ISMENIA, King, 1849.

Etym.—*Ismenius*, of or belonging to Thebes.

Syn.—*Terebratula* (?), Davidson, 1884.

Deslongchamps, who made *Ismenia* a sub-genus of his *Waldheimia*, described it as follows:—“ Shell more or less transverse, especially in the young age, sometimes provided with lateral wings, as in *Spirifer* or *Megathyris* (*Argiope*). Surface ornamented with thick longitudinal costæ, generally few in number, acute, or rounded, but always very prominent, crossed by strong transverse ridges or lines of growth, which produce an ornamentation broadly reticulate and elegant. Beak large and thick, truncated by a triangular foramen in young age, more or less rounded in the adult, sometimes in the middle of a flat area as in *Spirifer*; deltidium always slightly pronounced, remaining often incomplete in adult age. Beak of the ventral valve showing always in the interior well-marked rostral septa. In the interior of the dorsal valve the cardinal platform is slightly developed, and rests upon a median septum more or less pronounced, which reaches half the total length of the valve. The brachial apparatus takes its definite form only in adult age, the *Megerliform* stage persisting in *Ismenia* much longer than in the other groups which pass through various stages in the metamorphosis of the apophysary system" (12, p. 263).

Ismenia first makes its appearance in the Liassic rocks, where it is represented by *I. perrieri*, and *I. suessi*; E. Desl. sp. Both of these extremely rare and beautiful shells were found by Moore in the Middle Lias (*Margaritatus* zone) at Ilminster.

On the Continent, *Ismenia* is also met with in the Inferior Oolite, Fullers' Earth, Oxfordian and Corallian rocks. It is also found in existing seas.

Œhlert makes *Ismenia* a sub-genus of Bayle's genus *Mühlfeldtia*.

MEGATHYRIS, D'Orbigny, 1847.

Etym.—μέγας, great; θυρίς, a small opening.

Syn.—*Argiope*, Deslongchamps, 1842, non Savigny et Audouin, 1827; *Argiope* (?), Davidson, 1884.

A pretty little shell found by Moore in the Great Oolite of Hampton Cliff; was provisionally named by Davidson as *Argiope* (?) *oolitica*.

As there is some doubt of its being a *Megathyris*, we need not concern ourselves about a generic diagnosis of the genus. Davidson's description of this extremely rare shell is as follows:—

"Shell minute, wider than long; dorsal valve semicircular, of moderate convexity. Surface ornamented with thirteen rounded ribs, of which the central one is somewhat the largest. Ribs divided by interspaces of almost equal width; hinge-line as wide as the greatest breadth of the shell. Ventral valve slightly deeper than the opposite one; beak nearly straight; area triangular, flat, moderately broad, with a largish foramen in the middle; external surface ornamented, as in the opposite one, both valves being crossed by equidistant concentric lines of growth. Length one line; breadth one and a quarter. Nothing is known of the interior of this small shell" (9, p. 111).

M. megatrema, Sow. sp., from the Cretaceous rocks, and *M.* (?) *oolitica*, are the only species of this genus recorded for the whole of our British strata. One species, *M. decollata*, is found in existing seas.

ZELLANIA, Moore, 1854.

Etym.—Zella, a lady's name?

The generic characters of *Zellania*, as given by Moore, are as follows:—" Shell minute, unattached; foramen large and rounded, encroaching on both valves, or triangular; valves depressed and convex ; dorsal valve usually most so; external surface rugose, showing slight tendency to striation, at others having concentric lines of growth, which are more defined on the ventral valve; valves articulate. Interior of dorsal valve granulated or smooth, showing flattened, granulated or smooth margin, surrounded by an elevated ridge which, commencing under the dorsal sockets, passes to the front of the shell, where it is partly obliterated, and is then united by a central septum."

Moore adds that, " *Zellania* has affinities with *Thecidea*, in having internal ridges and a central septum; and will consequently unite the Terebratulidæ with the Thecideidæ. The probability of the existence of a loop such as that possessed by *Megathyris* (*Argiope*), has been suggested by Mr. Davidson; but although I have, in several instances, made dissections for the discovery of this loop, its existence cannot be satisfactorily established" (15, p. 107).

Zellania is apparently confined to the Jurassic rocks, where it is represented by six species, as follows:—

Z. davidsoni, Moore, type obtained from the Inferior Oolite of Dundry, where the species is stated by Moore to be not uncommon.

Z. globata, Moore, from the Fuller's Earth of Bath; Great Oolite of Hampton Cliff; and the Coral-rag of Lyneham, Wilts.

Z. laboucherei, Moore, type from the Inferior Oolite of Dundry, and at present in the Bath Museum. This species and *Z. davidsoni* is also recorded from the Lower Lias of Brocastle.

Z. liasiana, Moore, Upper Lias, Ilminster.

Z. oolitica, Moore, type from the Inferior Oolite of Dundry.

Z. obesa, Moore, type from the Lower Lias of Stouts Hill, Bitton.

THECIDEA, Defrance, 1822.

Etym.—*θήκη*, a chest or case.

This well-marked genus is considered by some authors to be allied to the Terebratulidæ by the presence of an internal loop, although it differs in many respects from any of the preceding genera, viz., by the absence of a foramen, its thickened shell and granulated margin, as well as general character and habits.

Thecidea first makes its appearance in the Jurassic rocks, where it is represented by fourteen species, including *T.* (?) *pygmæum* and *granulosum*, Moore. It is also found in the Cretaceous rocks, and in existing seas is represented by the sub-genus *Lacazella*.

For our knowledge of the Liassic and Oolitic *Thecidea*, we are mainly indebted to Charles Moore, in whose collection, in the Bath Museum, may be seen types of the following species :—

T. bouchardii, Dav., from the Inferior Oolite of Dundry.
T. duplicatum, Moore, ,, ,, ,, ,,
T. forbesi, ,, ,, ,, ,, ,,
T. septatum ,, ,, ,, ,, ,,
T. serratum ,, ,, ,, ,, ,,
T. moorei, Dav., ,, Middle Lias of Ilminster.
T. ornatum ,, ,, Coral Rag, Lyneham, Wilts.
T. (?) *pygmæum* ,, ,, ,, ,, ,,

Also described specimens of *T. triangulare*, d' Orb., from the Inferior Oolite of Dundry.

The fossil *Thecidea* are uncommonly small in this country ; on the Continent they are considerably larger. It is probably due to their being so small that they, and also *Zellania* and *Megathyris*, are often overlooked by collectors. At the request of Mr. Walker, a large quantity of the marly stuff from the upper beds of the Inferior Oolite of Dundry was recently forwarded to him. This he has washed down and examined for micro-brachiopods, and he informs us that he has found in it nearly all of Moore's small species which occur at Dundry. This shows that with careful search many of the species which are now considered remarkably rare may be obtained.

TABLE SHOWING APPROXIMATE NUMBER OF BRITISH JURASSIC BRACHIOPODA FIGURED AND DESCRIBED BY THE VARIOUS AUTHORS UP TO THE PRESENT TIME.[1]

	Species.	Doubtful Species.	Varieties.
Lingula	8		
Discina	11	1	
Crania	7		
Cadomella	2		
Köninckella	3		
Spiriferina	10	4	
Rhynchonella	62	2	11
Acanthothyris . . .	6		4
Terebratulina . . .	2	2	1
Disculina	1		
Terebratula { Terebratula, Glossothyris, Dictyothyris } . .	57	1	15
Waldheimia *auctorum.* { Eudesia, Flabellothyris, Zeilleria, Ornithella, Microthyris, Aulacothyris, Cincta, Plesiothyris, Orthoidea } . .	49	1	13
Terebratella . . .	3	1	
Ismenia	2		
Megathyris		1	
Zellania	6		
Thecidea	12	2	
	241	15	44

[1] All those species described in the Appendix are included.

In concluding this paper, I beg to tender my hearty and most sincere thanks to my friends, Messrs. S. S. Buckman, F.G.S., of Cheltenham, and J. F. Walker, M.A., F.G.S., of York, and especially to my old and esteemed friend and tutor, E. Wilson, F.G.S., Curator of the Bristol Museum, who have rendered me great assistance in the compilation of this communication.

Appendix.

Since the foregoing communication was made, I have received from Mr. Buckman a copy of his paper on "The Bajocian of the Mid-Cotteswolds" (*Quart. Journ. Geol. Soc.*, Vol. LI. Aug., 1895); and from the authors (Messrs. Buckman and Wilson) a copy of their paper, entitled "Dundry Hill: Its Upper Portion, or the Beds marked as Inferior Oolite (g. 5) in the Maps of the Geological Survey" (*Quart. Journ. Geol. Soc.*, Vol. LII., Nov., 1896). In these two works Mr. Buckman has named the following new species of Oolitic Brachiopoda.

RHYNCHONELLA.

Rhyn. cymatophora,[1] S. Buckman, Inferior Oolite, Bradford Abbas, Dorset. We have also found this species at Dundry. *Rhyn. cymatophora* was described in 1882, by Mr. Buckman, as *Rhyn. gingensis*, and was figured as such by Davidson in 1884.

Rhyn. cynoprosopa,[2] S. Buckman, Cephalopoda Bed of the Cotteswolds.

Rhyn. cynica,[3] S. Buckman, Yeovil Sands around Bradford Abbas, Dorset. This species was described in 1882, by Mr.

[1] κῦμα, wave; φόρος, bearing.
[2] κυνοπρόσωπος, dog-faced.
[3] κυνικός, dog-like.

Buckman, as *Rhyn. beneckei*; it was figured by that name by Davidson in 1884.

Rhyn. cynomorpha,[1] S. Buckman, Oolitic Marl of the Cotteswolds.

Rhyn. brasili,[2] S. Buckman, Inferior Oolite, Corton Downs, Somerset.

Rhyn. aff weigandi,[3] Haas and Petri. A small, globular *Rhynchonella* of the *cynocephala*-type, with uniplicate mesial fold not much elevated, found by Mr. Buckman in the Inferior Oolite of Drimpton and Netherton, in Dorset.

Rhyn. jurensis, var. *bothenhamptonensis*,[4] Walker, near Bridport, Dorset. This shell was omitted by me when dealing with *Rhynchonella* (*Geol. Mag.*, Dec. III., Vol. IX., No. 340, p. 437, Oct., 1892).

ACANTHOTHYRIS.

Mr. Buckman says there are at least four or five more new species of *Acanthothyris* in the Inferior Oolite of the Cotteswolds. He has not yet named them.

TEREBRATULA.

Ter. crickleyensis,[5] S. Buckman, Inferior Oolite, Charlton Common and Crickley Hill, Glos. This species was figured by Davidson in 1878 as *Ter. perovalis*, var. *Kleinii*.

Ter. uptoni,[6] S. Buckman, Inferior Oolite, Charlton Common, Glos. In 1878 Davidson figured this species under the name of *Ter. perovalis*.

[1] κυνομόρφος, dog-formed.
[2] Dedicated to M. Louis Brasil.
[3] Dedicated to Herr Weigand.
[4] Bothenhampton, a village in Dorset.
[5] Crickley, a hill in Gloucestershire.
[6] Dedicated to Mr. Charles Upton.

GLOSSOTHYRIS (?)

Mr. Buckman proposes to restore Deslongchamps' name *Gloss.* (*Ter.*) *brebissoni*,[1] for the shell figured by Davidson in 1884 as *Ter. curvifrons*, from the Dorset district, and to reserve the name *Gloss.* (?) *curvifrons* for those closely-allied forms found in the Cotteswolds.

ZEILLERIA.

Zeil. oppeli,[2] S. Buckman, Inferior Oolite, Burton Bradstock, Dorset.

[1] Dedicated to M. Brebisson.

[2] Dedicated to the celebrated German palæontologist, Dr. A. Oppel.

Reports of Meetings.

GENERAL.

THE present issue of the Proceedings of the Bristol Naturalists' Society includes, in addition to papers belonging to the past session, others read before the Society since the end of last year. This course has been adopted because it was thought undesirable that two communications should remain unpublished for nearly a year.

During the period represented by this issue of the Proceedings there have been twelve general meetings.

At the annual meeting, held January 16th, 1896, Dr. Sidney Young, F.R.S., delivered an address on the "Nature of Liquids and Gases," illustrated by experiments.

The meeting of February 6th was devoted to the exhibition of various objects of interest. Mr. C. H. Walker showed weapons from Uganda and an Indian cricket (*Schizodactylus monstrosus*). The Rev. R. Chichester two nests of the Red-backed Shrike, and a large series of eggs of the same bird. The points of interest in the nests were that in one instance the larder included an impaled female bird of the same species, and in the other that the young were albinos. Mr. G. C. Griffiths showed several cases of Lepidoptera, chiefly of the Coppers and Blues (*Lycanidæ*) ; and Mr. Mounteney various exhibits, of which the most interesting was a pair of Blue-headed Wagtails shot in May, 1890, near

Gloucester. Dr. Norton showed the nest of a Redstart built under an inverted flower-pot; Mr. S. H. Reynolds photographs of birds in the British Museum, and of natives of the Madras Presidency; and Mr. Stoddart specimens of a rare spider caught by himself in Bristol, and the only ones obtained in the British Isles. Dr. Young also sent a specimen of metallic chromium for exhibition.

On March 12th Professor Chattock gave a lecture on "The Cathode Rays and the New Photography," illustrated by experiments and lantern slides.

On May 7th Mr. G. C. Griffiths read a paper on "Some Lepidopterous Larvæ, their Habits and Means of Protection," illustrated by lantern slides and preserved larvæ.

On October 8th Mr. Charbonnier showed specimens of the Grey Phalarope recently shot; after which Professor Lloyd Morgan read a paper on "Further Observations on the Instincts of Young Birds."

On November 5th Dr. E. Fawcett gave a lecture on "A Bone—What is it? Why is it?"

On December 7th Mr. H. C. Playne read a paper on "Some Wanderings in the North of Finland."

The thirty-fourth annual meeting was held on January 14th, 1897, when Dr. S. Young gave an address on "Crystals." Models of some were shown, and the forms of others thrown upon the screen by means of a lantern.

The February meeting, held on the 4th of the month, was again devoted to the exhibition of natural history objects of varied interest. Mr. Charbonnier showed a specimen of the Giant Petrel; Mr. C. F. Druitt a series of platinotype views of birds' nests, lent by a friend in the North of Ireland; and Mr. S. H. Reynolds photographs of animals in the London Zoological Gardens. Mr. G. C. Griffiths exhibited several cases of British and foreign Lepidoptera, and Mr.

Mounteney nests of the Mud Wasp from Texas. Two specimens of stoat were also shown, shot near Taunton at the same time, one of the dark summer colour, and the other in the white winter coat. It was suggested that there may be two varieties, if not two species, of stoat. One, the larger of the two, does not vary in the colour of its coat at different times of the year, while the smaller one does. A clutch of eggs of the Pied Flycatcher was shown by Dr. Norton with the egg of a cuckoo found in the same nest. The last exhibit was by Mr. C. K. Rudge of dried fish preserved in a way which retained the natural appearance of the eye.

On March 4th Mr. S. H. Swayne read a paper on the "Homologies of Horn Structure in the Ungulata," after which a few notes upon an artesian well in San Marcos were read by Mr. Rudge for Dr. Fryer. At the depth of 188 feet water was struck, and flowed out at the rate of 1,100 gallons a minute. The water thrown out contained many animal forms, all blind and colourless. Amongst these were salamanders, but the most numerous a species of niphargus. Mr. Baker showed several minerals and crystals from South Africa, and a specimen of gold from Johannesburg.

The meeting that should have been held on April 1st was held a week earlier, on March 25th, conjointly with a meeting of the Microscopical Society, in order to hear a paper from Mr. E. M. Wilson, President of the Royal Microscopical Society, on "Microscopic Vision."

On May 6th Mr. H. W. Pearson read a paper upon "Local Surface and Underground Springs, and their Surrounding Strata," after which Mr. G. Brebner laid before the meeting some original observations affecting the classification of the Tilopteridaceæ.

THEODORE FISHER.

BOTANICAL SECTION.

FINALITY in local botany appears to be as far off as ever, and the field-botanists of the Bristol district continue to discover unexpected treasures year after year. One or two of our later discoveries have aroused interest throughout the country; notably Mrs. Gregory's announcement of the presence of *Scirpus Holoschœnus* in North Somerset, and the detection by Mr. Cedric Bucknall of a new British labiate (*Stachys alpina*) in West Gloucester. In a late number of the *Journal of Botany*, Mr. Bucknall has published some details respecting his plant, from which it will be seen that the new Stachys is surrounded in Britain by the same species that accompany it in Central Europe—the elevation of 650 feet a few miles north of Bristol being, to some extent, climatically comparable with that of 4,650 feet in South Tyrol.

A great deal more light has been thrown upon Bristol violets during the past season. Mrs. Gregory first showed that *V. calcarea* Bab. could be readily distinguished upon the limestone near Weston-super-Mare; and the species was afterwards recognised in other similar localities. The forms *lactiflora* and *rosea* of *V. hirta* have also been found, and likewise two well-marked hybrids between *hirta* and *adorata*. None of these were previously known in the district. Further, the great sedge in Berrow marsh is associated with *Juncus maritimus*—a rush which, although formerly recorded from the vicinity, has probably not been gathered near Bristol during the present generation. Among other finds, *Hieracium murorum* is new to the district; and *Hypericum dubium*, *Rubus rudis*, and *Monotropa* are new to the Gloucestershire division. One of the Saturday excursions made us acquainted with *Arenaria tenuifolia* at Pilning; and this rarity has also been observed in good quantity at Newton St. Loe.

JAS. W. WHITE, F.L.S.

CHEMICAL AND PHYSICAL SECTION.

DURING the session three meetings were held, and the following papers read :—

November 26th.—"On Some Lecture Experiments in Static Electricity," by Mr. D. Rintoul. "On Some Chemical Experiments," by Mr. W. A. Shenstone. "On Some Experiments on High Vacua," by Professor A. P. Chattock.

January 26th.—"On Explosions in Coal Mines from Gases derived from Coal Dust," by Mr. Donald M. Stuart.

March 23rd.—"On the Action of Chloroform and Potash on Amido-benzoic Acid," by Mr. W. J. Elliott. "On the Combustion of Carbon," by Mr. E. H. Strange. "On the Composition of American Petroleum," by Dr. S. Young.

LLEWELYN N. TYACK, *Hon. Sec.*

ENTOMOLOGICAL SECTION, 1896-97.

NO excursions were taken during the summer of 1896. Five meetings were held during the winter. No papers were read, but some interesting specimens have been exhibited, as follows:—

November 10th.—Mr. Mounteney showed some fine examples of *Lycæna arion* taken on the Cotteswolds this year.

December 15th.—Mr. G. C. Griffiths exhibited some varieties of the Lepidoptera, amongst others being *Lubricipeda* vars. *fasciata* and *radiata* ; *Menthastri* vars. *carbonica* and *ochracea* ; and *Viminalis* var. *obscura*. Mr. Harding exhibited a large number of species of Lepidoptera injurious to garden and farm crops. There were also shown some figures of the ova of Lepidoptera drawn by Mr. Wheeler.

At the annual meeting held on February 23rd the following resolution was passed : "That Entomologists not residing in Bristol be asked to become Honorary Corresponding

Members of the Section." Since this, Messrs. J. Mason, R. M. Prideaux, and C. J. Watkins, have been asked, and have consented, to join the section under this rule.

On March 16th the meeting was held at Caledonia Place, by invitation of Mr. Griffiths, who exhibited a large number of Lepidoptera, of which a few specimens of the Queensland skipper *Euschemon Rafflesiæ* were perhaps the most interesting. There has been some doubt and discussion as to whether this species is a moth or a butterfly, the insect having the frenulum of the moth, but the antennæ with other characters of a Hesperid butterfly. Mr. Griffiths showed by some pupæ and preserved larvæ that it undoubtedly belonged to the butterflies.

The meetings held on November 10th and April 13th were held at Rupert House, by the kind invitation of Mr. S. Barton, when large numbers of fine and rare specimens of Coleoptera and Lepidoptera were inspected.

CHARLES BARTLETT,
Hon. Sec.

GEOLOGICAL SECTION.

THE numbers of the sectional members remains practically constant. Mr. A. E. Hudd and Mr. F. Ashmead, valued members of long standing, have resigned, but some new members are about to join. Two meetings were held in 1896, the first on March 26th, when Mr. S. H. Reynolds read a paper on "Petrology," illustrated by lantern slides. On December 16th Mr. E. Wilson, F.G.S., read a paper on "The Beds capping Dundry Hill mapped as Inferior Oolite by the Geological Survey." This paper will appear in print in the Proceedings in due course. An excursion to Westbury to visit the Ironstone beds was taken on Saturday, the 18th of July.

Several papers have been promised for this Session, and there is more hope of better meetings.

It is desirable that more excursions should be arranged, as they conduce to an exchange of views, and form pleasant opportunities for meeting others interested in Geology.

The financial position of the Section shows a balance to its credit.

A. W. METCALFE.

ORNITHOLOGICAL SECTION.

THIS section was formed in November, 1896, and now consists of twelve members.

Besides meeting for the purpose of discussion and of hearing papers read, it is proposed that the section should make a list of the Bird Fauna of the neighbourhood.

Since the preliminary meetings two have taken place as follows:—

Jan. 28th, 1897, Mr. S. H. Reynolds gave a paper on Skeletons of Birds, illustrated by numerous specimens and drawings.

March 29th, Mr. H. J. Charbonnier exhibited many specimens and gave a paper on various forms of Wings and Feathers.

The President, Prof. C. Lloyd Morgan and Mr. Charbonnier also showed lantern slides to illustrate flight and other points.

HERBERT C. PLAYNE,
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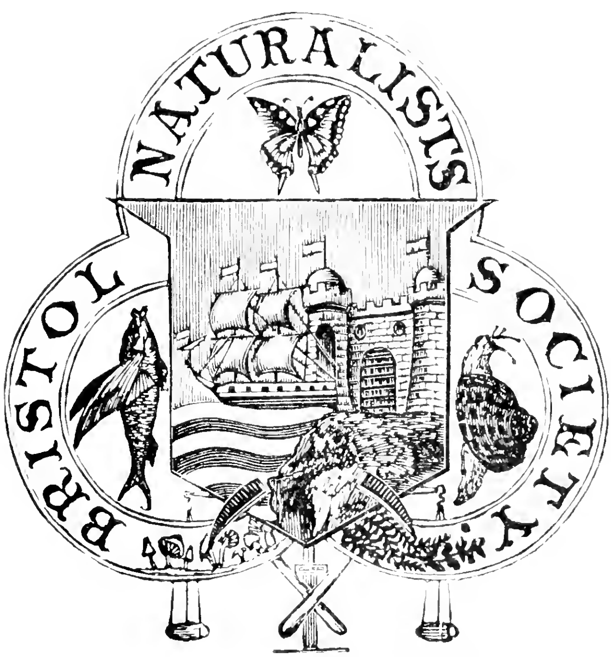

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By SIDNEY F. HARMER, Sc.D., F.R.S.,

Fellow of King's College, Cambridge, and Superintendent of the University Museum of Zoology.

THE last fifty years form a memorable period in the history of Zoophytology in this country. It says not a little for the value of the work done in this department of Zoology by Mr. Thomas Hincks that his name stands out prominently even in a period which includes the publications, on similar subjects, of Allman and Busk. The student of the Marine Zoology of the British Islands owes a deep debt of gratitude to Mr. Hincks for his well-known monographs, "A History of the British Hydroid Zoophytes" (1868), and "A History of the British Marine Polyzoa" (1880). The former, which was published shortly before the appearance of Allman's monumental treatise on the Gymnoblastic Hydroids, still remains the only modern hand-book which deals with British Hydroids in general; the latter has at no time had any rival. All zoologists who have made collections at the sea-side must have experienced difficulties in determining the species of even the commonest marine animals. The student of British

Hydroids or Polyzoa is in a more fortunate position, the labours of Mr. Hincks having put it in his power to ascertain the species which he wishes to investigate without having recourse to a literature scattered through the scientific journals of many countries. Mr. Hincks' treatises are not merely a compilation from the works of others, but they give evidence throughout of independent investigation of the objects described. Our admiration is excited equally by the exactness of the original observations of the author and by the care which has been taken in collecting and incorporating the labours of others. The work is that of a master in his subject, and every page bears the impress of accuracy and sound judgment. Work of this character is of inestimable value, not only to the systematist, but also to other zoologists who approach the subject from different standpoints.

Mr. Hincks' investigations have by no means been confined to the British Fauna, but his activity in the study of foreign species has shown itself in a long series of papers contributed to the *Annals and Magazine of Natural History* and other journals, at frequent intervals from about 1850 till quite recently. The earlier papers of this series are devoted almost equally to Hydroids and Polyzoa; but latterly Mr. Hincks has turned his attention more and more exclusively to the Polyzoa, on which he is admittedly the first authority of the present day. The series of papers entitled *Contributions towards a General History of the Marine Polyzoa* were recently republished in a collected form, and a glance at the index of this most valuable collection is enough to show how many species have received their first description at the hands of Mr. Hincks. The diagnoses which are given are models of accuracy, and usually enable the species to be recognised by others with little of the uncertainty which is felt in using the descriptions of less accomplished observers.

The classification of Cheilostomatous Polyzoa was revolutionized by the acceptance of Smitt's principle that the characters of the individual or "zoœcium" are of more importance than those of the entire colony. This view was warmly supported by Mr. Hincks, who has carried it to its logical conclusions throughout his investigations. The student of the Polyzoa was at one time able to refer the majority of encrusting calcareous Cheilostomes to the genus *Lepralia*, while an erect bilaminate colony could be safely called an *Eschara*. Mr. Hincks showed on what unsatisfactory grounds these associations rested; and although there may be some loss of convenience in giving up the older genera, which could be recognised at once with the naked eye, there can be little doubt that the newer principles of classification were a surer test of affinity than the habit of the entire colony. Such at least is the view of recent writers, who consistently adopt the conclusions which Mr. Hincks did so much to establish.

Though Mr. Hincks' services have been so great in the domain of systematic zoology, the Natural History of both Hydroids and Polyzoa has come in for a large share of his attention, and the pages of his two monographs on the British forms abound with interesting observations on the characters and behaviour of the living animal. The "Introduction," in the case of each of these works, gives an excellent general account of the group.

The *Royal Society Catalogue of Scientific Papers* for the years 1800–1883 includes the titles of forty-eight memoirs by Mr. Hincks, some of them consisting of several parts published at different times. The very first of these, which appeared in the *Annals and Magazine of Natural History* for November, 1851, will serve well to illustrate the interesting nature of so many of Mr. Hincks' memoirs. After some account of the movements and functions of avicularia and vibracula, important observations on the so-called "intertentacular organ" of *Membranipora pilosa* are described. This structure was discovered in 1837 by Farre, but escaped the observation of almost every one except Mr. Hincks until Prouho quite recently published some results of great interest on this subject. Mr. Hincks' paper then deals successively with the living polypides of several species, the remarkable bivalved larvæ of *Flustrella hispida*, the interesting genus *Mimosella* (here first described), whose zoœcia continually move backwards and forwards on the stem, a species of *Pedicellina* new to the British Fauna, and the mode of escape of the larvæ of *Alcyonidium* from the parent colony.

This is only one illustration out of many which might be given. The value of Mr. Hincks' results cannot be better illustrated than by saying that no extended study of the Marine Polyzoa is possible without constant reference to his work. The writer of the present article, who has learned, by correspondence with Mr. Hincks, to appreciate the kindness and courtesy of his disposition, and to be grateful for the words of encouragement so readily given by him to a younger worker in the same field, has no little satisfaction in acknowledging here the warm admiration which he feels for Mr. Hincks' published memoirs.

The Argument for Solidity Drawn from Ocean Tides.

By A. VAUGHAN, B.A. (Cantab.), B.Sc. (Lond.).

THIS paper deals only with the argument for solidity deduced from the existence of a fortnightly ocean tide, caused by the moon's attraction.

Were the interior of the earth fluid, it is assumed that sea-floor and water would rise together, and, therefore, the tide be inappreciable. It seems, however, probable that the tide would reach a very small value along coast lines, where the waters of the ocean are held back in their motion, whilst the tide in the interior would almost certainly move as demanded by theory.

It had been generally assumed, until recently, that the movement of the water in the fortnightly tide might be neglected, on account of the long period of oscillation, and that, in calculating the height of the tide, the equilibrium theory would give a very close approximation. It has, however, been shown by Professor Darwin, by the employment of Laplace's method, that, in oceans of uniform depth, not greater than 1,200 fathoms, the motion of the water has a very appreciable effect, namely, a diminution equivalent to at least halving the equilibrium value. There must also be a further reduction owing to the fact that a solid earth could not be absolutely rigid; if as rigid as steel, the tide should reach about two-thirds of its equilibrium value.

Introducing the actual figures, we have for the case of a solid earth :—

(1) Due to equilibrium theory: the fortnightly tide at the equator should range about ·07 ft. above and below a mean level.

(2) Applying Professor Darwin's kinetic correction, the range should only be ·035 ft.

(3) For an earth no more elastic than steel, the range would be ·023 ft. (*i.e.* about ¼ in.).

This small amount is the greatest height the tide could reach at the equator; at places farther North and South, the tide will be smaller, until, at about 35° latitude, the height will be zero.

It is clear, then, that the determination of the fortnightly tide must be made between the equator and the thirty-fifth parallel; that the ocean should be unencumbered and deep; that the water near the observatory should not be shallow; and that the observatory should not be within a rapidly narrowing estuary.

All these desiderata point to the Indian ports as by far the best suited to the purpose; and, at Lord Kelvin's suggestion, tidal stations have been set up at many points along the coasts of Burma, India, and Ceylon, and the results analyzed, with the object of determining the rigidity of the earth.

Colonel Baird, R.E., who for several years was in charge of these observations, has kindly obtained for me the complete tidal determinations at each of the Indian ports up to the end of the year 1894. These results are given in feet, and represent the average, throughout each year, of the observed fortnightly tide corrected to the moon's mean orbit.

It is important to notice that any cause, whose period approximates to a fortnight, even if acting for a small part of the year, and that discontinuously, must necessarily have its effect included in the measured fortnightly tide.

I have derived the results tabulated below from the above-mentioned tidal reports, and by calculation; those ports only being selected at which observations extend over at least six years. In the first column is the name of the place; in the second, its latitude; in the third, the least and greatest yearly values since observations have been made; in the fourth, the mean of the yearly observations; in the fifth, the theoretical tide calculated on the equilibrium theory; in the sixth, the same value corrected for motion by Professor Darwin's method; and in the last, the further correction for a globe as elastic as steel.

Name.	Latitude.	Min.-Max.	Average.	Height on Equilibrium Theory.	Corrected for Motion.	And for an Interior as Elastic as Steel.
Karachi . .	24°·48′	·004–·078	·036	·031	·016	·010
Bombay . .	18°·57′	·015-·083	·054	·046	·023	·015
Do. (Prince's Dock) . .	18°·55′	·023–·079	·050	·046	·023	·015
Vizagapatam	17°·41′	·030–·082	·054	·049	·024	·016
Madras . .	13°·5′	·020–·056	·044	·057	·028	·019
Aden . . .	12°·47′	·012–·065	·043	·058	·029	·019
Port Blair .	11°·41′	·025–·067	·050	·059	·029	·019
Beypore . .	11°·10′	·022–·118	·068	·060	·030	·020
Cochin . .	9°·58′	·025–·072	·056	·062	·031	·021
Colombo . .	6°·57′	·015–·066	·043	·065	·032	·022
Galle . . .	6°·2′	·012–·073	·038	·065	·033	·022

We have now only to discuss these results.

If the observed fortnightly tides are made up mainly of a periodic motion of the waters, due to the action of the moon upon the oceans of a solid attracting globe, these tides, or at least their average amounts, should obviously satisfy the following conditions:—

(1) The tides at any one place should not differ considerably from year to year.

(2) The tides at two places on the same, or very close, latitude should be the same, or very nearly the same, however far apart their places may be in longitude.

(3) A place nearer the equator should have a higher tide than one more remote.

(4) There should be an agreement in amount at each place with the corrected theoretical value for that latitude.

From the actual results as tabulated the obvious conclusions are:—

(1) The greatest variation for different years is, in almost all cases, as great as, or greater than, the average tide at that place; since this variation must be due to causes other than a moon-caused vibration, these other causes must be at least of the same order of importance as the theoretical one.

(2) The average tides do not increase regularly towards the equator, but roughly increase from the higher latitude up to about 11°, and then diminish again towards the equator.

(3) The average observed height is always far in excess of the corrected theoretical height, and, in fact, in the majority of cases, is much nearer the uncorrected equilibrium value. (It is worth noticing that the average of the actual tides for all ports, allowing weight for the number of observations at each, is about ·95 of the average theoretical height, calculated on the equilibrium theory and uncorrected. This is very approximately the conclusion at which Professor Darwin

arrived in his original determination conducted on the same theory.)

It must, however, be remarked that, since the observations are conducted in shallow water near the coast line, the observed values must be exaggerated by the heaping up of the water caused by actual transference. The same cause would produce higher tides the less open the sea; so that the nearer the equator the more accurate the results. It need scarcely be pointed out, however, that this reasoning would apply equally to almost any possible cause.

Finally, it seems clear that, after making every allowance possible, the results of observation do not definitely, or even approximately, prove the existence of a fortnightly tide depending upon the moon's action alone, and obeying certain definite laws.

Much might be learnt by establishing stations in those latitudes where the theoretical tide should vanish, and also by estimating the fortnightly component at ports North of this latitude. Only if it were found that at such places a fortnightly tide is practically non-existent could it be considered proved that a moon-caused fortnightly tide is an established fact.

At present the observations cannot be considered to disprove a fluid interior.

Some Notes on Lepidoptera from the Painswick District.

By C. J. WATKINS.

IN the spring of this year, of hybernated butterflies *Gonopteryx rhamni* and *Vanessa urticæ* were seen here on March 21, but last year (1896) I saw *V. urticæ* flying in January. The first observation in my oldest note-book records the appearance of this welcome butterfly on December 18, 1866. I have failed to notice *V. C. album* in our garden this year, but last year it was first seen on March 24. I have bred this interesting species several times from larvæ or pupæ found on gooseberry and red currant bushes. In the *Entomologist* for September, 1871, will be found an account of my first brood, where I, at the same time, ask Mr. Newman a question as to its being double-brooded. This summer the Cabbage Whites have been very abundant, and probably *P. brassicæ* was the worst pest of them.

Last year, on February 15, I received from Barnsley, Yorkshire, a living specimen of *P. rapæ*, caught in a garden there on the previous day. When the cuckoo flower (*Cardamine pratensis*) appears, we expect to see the ♂ (*A. cardamines*) taking its first flight along the brookside meadows. My earliest yearly record of it is April 11, 1869, and the latest first specimen seen was on June 11, 1887. In 1875, on July 2, I saw one in good condition. This year (1897) the first ♂ was seen on April 27. Once only I found the pupa in winter, on February 21, 1871, attached to the stem of a wild rose, and bred it during the spring.[1]

Colias edusa I have never seen in numbers, and it only occurs occasionally, and usually single specimens. It was caught near Painswick this year on September 11, by a young collector from London.[2]

G. rhamni is getting scarcer in this district.

M. galatea has been fairly common this year in its haunts. I bred this sluggish flying butterfly in 1869 from larvæ found on June 11, on Painswick Hill; the first imago emerged on July 17.

S. semele is not seen so often as in former years.

E. tithonus is not common here any season.

E. hyperanthis sometimes common, but certainly local. I generally see it in one locality each summer, and formerly took several interesting varieties of it.

T. W. album formerly occurred close to our mill, and on July 1, 1868, one was found by my brother at rest in the mill on the machinery. I have not seen it for some years, but think Mr. Merrin has taken it this season near Gloucester.

T. rubi, one of our early butterflies. This year I saw it on April 28. I have found it much worn in past seasons, as late as June 14.

L. adonis. I met with imagoes of the autumn brood of this lovely insect this year on September 14, in fair condition, on our hills, after an absence of several years. Previously I had only seen the summer brood here.

L. corydon was taken here this year during August.

[1] Emerged during the *evening* of April 30, 1871, a ♀. [2] List given.

L. alsus. I have not seen our Little Blue here this season, although it may have occurred in some of its local haunts where formerly it sometimes was found freely, and I have counted as many as twenty at rest on the herbage over a very limited space. Last year I saw several on Durlestone Head, Swanage, on sea-pink flowers, early in June.

L. argiolus seems to appear more freely here than formerly. Some seasons it has been observed as early as the first week in April. This year I saw it in our garden on April 28, and on August 1, over the same shrubs, I found a fresh specimen of the second brood. I once observed specimens of the second brood in July alighting in an open drain in our mill-yard to sip the sewage. This curious instance is noticed by Mr. Newman in his *British Butterflies*, page 136.

L. arion. Twenty-nine years ago I first met with this rare species on the Painswick Hill, and thoughtlessly published its capture in the *Entomologist* in 1868, which account Mr. Newman transferred to his *Butterflies*, pages 139, 140. Year after year fresh collectors appeared on our hills to reduce their numbers: and whatever various writers assert to the contrary, its almost total extinction in its old haunts is owing to *over-collecting.* Personally I have not taken a specimen for ten years, although I have seen single specimens on the boards of a friend, who told me he took them outside the old localities: and I am informed that it has been taken this season in a new locality, which we much fear will soon share the fate of the "old spots" in being over-collected.

In May, 1870, Mr. Buckler urged me to try for the hybernated larvæ to enable him to complete its history. This searching had to be done after business hours, and after a tramp of two miles to the most likely patches of wild thyme, which I usually searched on all fours before sunset. I could not find Arion, but came across other kinds of larvæ very acceptable to Mr. Buckler.

Last year a friend in Kent brought home from Cornwall some patches of thyme with Arion larvæ on it, hoping to find them live through the winter. This spring he was looking forward to see the hybernated larvæ (which we understand has been found on the continent) feeding on the new shoots of the food plant, when one day the wretched cats destroyed the young thyme and his hopes. Again he has visited Cornwall this season, and saw eggs deposited on thyme, which have been safely brought home to Kent, and we trust his laudable efforts will be crowned with success and his great desire to obtain figures of full-grown larvæ and pupæ be accomplished. He tells me that some of the best Arion ground in Cornwall is enclosed and about to be ploughed.

Mr. J. T. Stephens, jun., of London, who has, with his brothers and sisters, collected Lepidoptera here this year during August and September, at my request sent me a list of their butterfly captures during those two months. This list of the Painswick district species (which I give later on) is of much interest to me, since, owing to my inability to get about as I formerly did, I have not of late years seen several of the butterflies he mentions, although I used to take them all, besides others, in the same localities. This will be seen by referring to the list of Gloucester Lepidoptera published in Witchell and Strugnell's *Fauna and Flora of Gloucestershire*, where I have attempted to show the records of all the Gloucestershire observers I could then obtain, showing 58 species to have been observed in our county out of the 67 of the British list: and it may be of interest to add that 588 species of Macro-Lepidoptera are there recorded for Gloucestershire, out of the British total of 823.

List of Butterflies taken during August and September, 1897, by the united efforts of the young members of a London family, in the Painswick district:—

Pieris brassicæ . . .	Aug. 7, Sept. 20.
,, napi . . .	July 29.
,, rapæ . . .	Aug. 7 and 14.
Gonopteryx rhamni . .	Aug. 14.
Colias edusa . . .	Sept. 11.
Argynnis aglaia. . .	July 31 and Aug. 1.
,, adippe . .	Aug. 1 and 14.
Vanessa C. album . .	Aug. 30 and Sept. 11.
,, urticæ . . .	Aug. 30.
,, io . . .	Aug. 11.
,, atalanta . .	Aug. 14 and Sept. 19.
,, cardui . . .	Aug. 6 and Sept. 7.
Melanargia galatea . .	Aug. 1 and 11.
Pararge egeria . . .	Aug. 11 and 12.
,, megæra . .	Aug. 12.
Epinephele ianira . .	Aug. 13 and Sept. 20.
,, hyperanthes .	Aug. 3 and 5.
Cœnonympha pamphilus .	Aug. 7.
Lycæna alexis-icarus . .	Aug. 23 to 30, and Sep. 14.
,, medon-agestis .	Aug. 11 and 16.
,, adonis-bellargus .	Aug. 31 and Sept. 1 up to 21.
,, argiolus . .	Aug. 3, 4, 5.
Hesperia thaumas . .	July 31.
Lycæna corydon . .	Aug. 11, 19, 20.

A veteran entomologist, who collected Lepidoptera around Painswick from the 27th June to 16th July, 1894 (several days were stormy), kindly drew me up a list which included 27 butterflies and 73 moths.

Reports of Meetings.

GENERAL.

THE present issue of the Proceedings of the Bristol Naturalists' Society is a very small one. It will be remembered that the preceding number was unusually large, representing, as it did, more than one year's work, and papers that strictly should have found a place in this issue were inserted there in order to avoid delay in publication. A list of the birds of the neighbourhood, it was hoped, would have appeared now, but those members of the ornithological section who have undertaken the work, although they have already spent much time and trouble in order to ensure accuracy, have desired to withhold the list until the publication of the next number of the Proceedings. One other reason for the small size of this issue may be mentioned. The papers read before the general meetings of the Society may be described as having been educational rather than original, and therefore not worthy of publication. In the interests of the majority of the members of the Society, it is perhaps desirable that the papers should be more of that character. A communication, based upon original work, is appreciated only by the few. It is hoped, however, that the sectional meetings of the Society will still furnish the Proceedings with material worthy of the consideration of members of other societies.

The following meetings were held during the winter session of 1897:—

On October 7th Mr. George Brebner gave a lecture on "Algæ," illustrated by lantern slides.

On November 4th Dr. Theodore Fisher gave an account of the "Migration of Birds," also illustrated by lantern slides.

On December 2nd the Rev. A. C. Macpherson read a paper on "Nature in the Nature Poets."[1]

THEODORE FISHER.

ORNITHOLOGICAL SECTION.

(April—December, 1897.)

THIS section started the second year of its existence on October 28th, 1897, with an interesting account of the birds of Lapland, given by Mr. H. C. Playne, who had but lately returned from a tour in that country. Prof. C. Lloyd Morgan consented to remain as President, and Mr. Price was elected Secretary of the section.

On November 25th a discussion on "Bird Vision" was started by the Secretary, who gave a short description of the anatomy of the avian eye.

On December 23rd Dr. Fisher introduced a discussion on "Change of Colour in Plumage" by some remarks on the various forms of moult, and Mr. H. J. Charbonnier exhibited feathers which demonstrated these forms.

The section consists of twelve members, and the attendance at meetings is satisfactory.

D. T. PRICE.

[1] This paper, it is hoped, will be published in the next number of the Proceedings.

PHYSICAL AND CHEMICAL SECTION.

ONLY one meeting was held during the winter session of 1897.

On December 15th the members of the section joined with the Geological Section (by invitation of the latter) to hear Mr. Vaughan's paper on "The Interior of the Earth."

LLEWELYN N. TYACK,
Hon. Sec.

ENTOMOLOGICAL SECTION.

Summer and Autumn, 1897.

ONLY one excursion was taken during the summer of 1897, the others arranged falling through from unsuitable weather. At the Clevedon trip very few specimens were taken, principally Diptera and Hymenoptera, the drenching rain preventing much collecting.

On November 9th Mr. C. J. Watkins, of Painswick, communicated a paper, entitled, "Some Notes from the Painswick District." This contained records of, and times of appearance of, many species, principally Lepidoptera. Mr. G. C. Griffiths exhibited some specimens of *Tephrosia binudularia* and *crepuscularia* from Leigh Woods, this locality being one of the places in the country where the two species are taken.

CHARLES BARTLETT.
Hon. Sec.

GEOLOGICAL SECTION FOR 1897.

THE first meeting of the Section during this year was held on March 24th. A hearty vote of thanks to the retiring Hon. Secretary, Mr. A. W. Metcalfe, was passed, and Mr. H. Pentecost was elected in his stead. An exhibition of lantern slides and enlarged photographs of rock sections was given by Mr. S. H. Reynolds, and later Professor Lloyd Morgan exhibited slides illustrative of the geological features of the Lake District. During the summer members of the section were kindly invited by Professor Lloyd Morgan to join certain excursions of his geological class. Members were, however, slow in availing themselves of this privilege, and on the first occasion only one member of the section was present. On December 15th a joint meeting of the Geological and Physical Sections was held, and Mr. A. Vaughan read a paper upon the character of the interior of the earth. This meeting was a most successful one, and the discussion was both animated and long.

There are now twenty-three members of the section, but the attendance at the meetings has been small. The financial position of the section is sound, although several members are in arrears. The Secretary is anxious to make the meetings more frequent, and will be glad to hear from any member who will read a paper or contribute to the section a note upon some point of geological interest.

H. PENTECOST,
Hon. Sec.

List of Societies to which the Proceedings of the Bristol Naturalists' Society are sent.

Barnsley Naturalists' Society.
Barrow Naturalists' Field Club.
Bath Natural History and Antiquarian Field Club.
Belfast Naturalists' Field Club.
Birmingham Natural History and Philosophical Society.
British Museum Library.
British Museum (Natural History), S.W.
Cardiff Naturalists' Society.
Chester Natural Science Society.
Clifton Antiquarian Club.
Cotteswold Naturalists' Field Club.
Cumberland Association for the Advancement of Literature and Science.
Dorset Natural History and Antiquarian Field Club.
Dudley and Midland Geological Society and Field Club.
Dulwich College Science Society.
Ealing Microscopical and Natural History Club.
Edinburgh Geological Society.
——— Royal Botanic Society.
Essex Field Club.
Geologists' Association.
Glasgow Geological Society.
——— Microscopical Society.
——— Natural History Society.
——— Philosophical Society.
Hampshire Field Club.
Hertfordshire Natural History Society and Field Club.
Huddersfield Naturalists' Society.
Liverpool Geological Association.
——— Geological Society.
——— Literary and Philosophical Society.
——— Science Students' Association.
Manchester Geological Society.
——— Literary and Philosophical Society.
——— Museum Library.
——— Microscopical Society.
Marlborough College Natural History Society.
Mining Association and Institute of Cornwall.
Norfolk and Norwich Naturalists' Society.
Nottingham Naturalists' Society.
Penzance Natural History and Antiquarian Society.

Plymouth Marine Biological Association of the United Kingdom.
——— Institution and Devon and Cornwall Natural History Society.
Quekett Microscopical Club.
Royal Cornwall Geological Society, Penzance.
——— Polytechnic Society, Falmouth.
Royal Institution of Cornwall.
Royal Microscopical Society.
Rugby School Natural History Society.
Somersetshire Natural History and Archæological Society.
Stockport Naturalists' Society.
Torquay Natural History Society.
Warwickshire Natural History and Archæological Field Club.
Wiltshire Archæological and Natural History Society.
Woolhope Natural History Field Club.
Yorkshire Geological and Polytechnic Society.
——— Naturalists' Union.
——— Philosophical Society.

AUSTRIA.

Iglo Hungarian Carpathian Club.
Wien, K. K. Naturhistorisches Hofmuseum.

FRANCE.

La Société Linnéenne de Lyon.

GERMANY.

Cassel, Verein für Naturkunde.
Frankfurt a/O.—Naturwissenschaftlicher Verein für den Regierungsbezirk F. a/O.
Kaiserliche Leopoldinische-Carolinische Deutsche Akademie der Naturforscher, Halle a/S. Preussen.
Oberhessische Gesellschaft für Natur- und Heilkunde, Giessen.

NORWAY.

Det Kongelige Norsk Universitet i Christiania.

RUSSIA.

Kieff Naturalists' Society.

SWITZERLAND.

Société Vaudoise des Sciences Naturelles, Lausanne.
Zürich, Naturforschende Gesellschaft in Zürich.

AUSTRALIA.

Australasia Geological Society.
New South Wales Geological Survey.
Royal Society of New South Wales.
Royal Society of Victoria.

CANADA.

Canadian Institute, Toronto.
Nova Scotian Institute of Natural Science (Halifax).

INDIA.

Geological Survey of India, Calcutta.

ARGENTINE REPUBLIC.

National Academy of Sciences, Cordoba.

CHILI.

Santiago (German) Scientific Society.

MEXICO.

Mexico Sociedad Cientifica.

UNITED STATES.

American Museum of Natural History, New York.
Boston (Mass.) Natural History Society.
Californian Academy of Sciences.
Cincinnati Natural History Society.
Essex Institute, Salem (Mass.).
Missouri Botanical Gardens.
Missouri, St. Louis, Academy of Science.
Newport (R.I.) Natural History Society.
New York Microscopical Society.
North Carolina (Chapel Hill) Elisha Mitchell Scientific Society.
Ohio Laboratories and Scientific Association of Denison University.
Philadelphia Academy of Natural Sciences.
Philadelphia Wagner Free Institute of Sciences.
Smithsonian Institution, Washington.
South Carolina: Elliott Society of Science and Arts, Charleston.
United States Geological Survey of the Territories, Washington.