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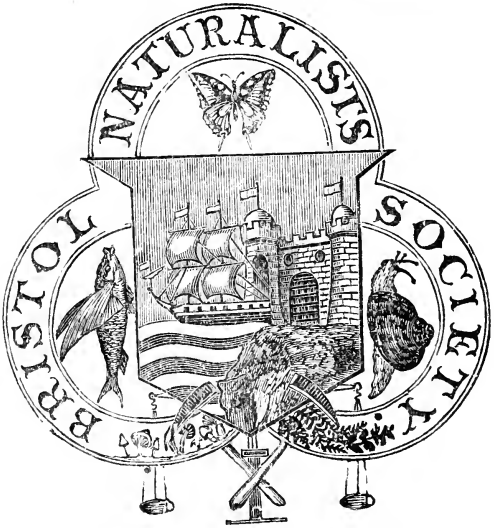

"*Rerum cognoscere causas.*"—VIRGIL.

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REPORTS OF MEETINGS AND EXCURSIONS.

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ERRATA TO VOL. I. PART. I,

Page 11, line 13, column 2—for "reticulata" read "subreticulata."
...... 12, ... 7 from bottom—for "Coronata" read "coronata."
...... 13, ... 3—for "in the state of" read "in the present state of," &c.
...... 23, ... 12—for "Murchisoni" read "Murchisonæ."
...... 42, ... 15—for "Greatest height" read "Greatest breadth."
...... 97, ... 11 from bottom—for "acerasum" read "acerosum."
...... 118, ... 15—for "Combrash" read "Cornbrash."
.... 16—for "Finest" read "Forest."
...... 101, ... 2 & 14 from bottom—for "Tetnemorus" read "Tetmemorus."
...... 111, ... 20—for "realy" read "really."
...... 121, ... 11 from bottom—for "molton" read "molten."
...... 127, ... 8—for "Arancida" read "Araneida."
...... 128, ... 8—for "Gracilis" read "gracilis."
...... 132, ... 18—for "in *situ*" read "*in situ.*"
...... 136, ... 10 for "Agrius" read "*Agrius.*"
.... 16—for "Necrophorus" read "*Necrophorus.*"
.... 15—for "Hydrodephaga" read "*Hydrodephaga.*"
...... 137, ... 7—for "Lema" read "*Lema.*"
...... 138, ... 8—for "Vestebra" read "*vertebra.*"
...... 139, ... 8—for "Aricula" read "*Avicula.*"
.... 16—for "the circumstances" read "these circumstances," &c.
.... 19—for "and not" read "and is not," &c.
...... 140, ... 16—for "at the top" read "at the base."

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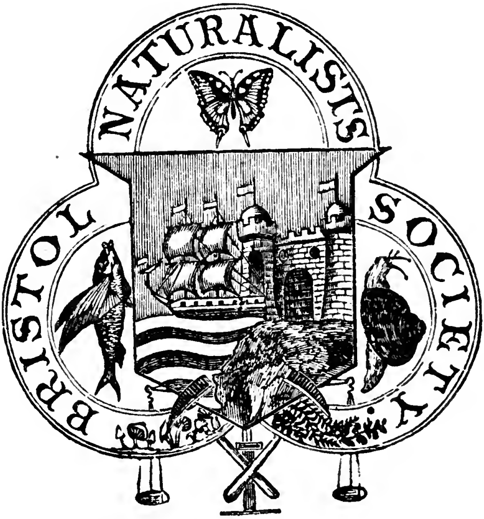

"*Quia planè fatemur Historiæ Naturalis et Experimentalis collectionem, qualem animo metimur, et qualis esse debet opus esse magnum et quasi regium, et multæ operæ atque impensæ.*"—BACON. Nov. Org.

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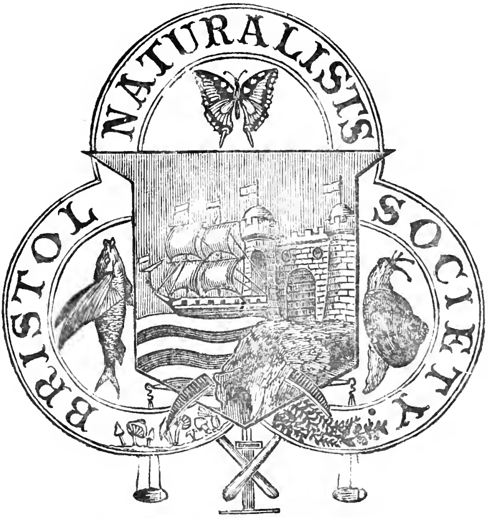

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The Society is indebted to Messrs. W. W. Stoddart and E. Tawney for the Woodcuts and Plates which illustrate their respective papers. It is also indebted to Messrs. J. E. Jose and E. Tawney for the device which now adorns our cover for the first time.

On Ethnic Migrations.

BY JOHN BEDDOE, M.D., F.R.S., M.A.I.

Read at the General Meeting, March 6th, 1873.

ETHNIC migrations may be divided into two classes:—

1st. Those into countries previously unoccupied.

2nd. Those into countries already inhabited.

Examples of the first kind are far less numerous than those of the second. In the ancient world, as known to the Greeks and Romans, there were really no countries unoccupied, except perhaps some portions of the Sahara, which were unfit for human habitation. The earliest recorded example of such migration is the colonization of Iceland, by certain chiefs of Norway. Their country had been conquered by Harold Harfager, and not choosing to submit to his authority, they determined to leave their native land and settle in Iceland, then only a desert. Some of them even attempted to settle in Greenland, but were in the end unsuccessful,—partly from the nature of the country, and partly on account of the opposition they subsequently met with from the Esquimaux, themselves settlers from some remote region.

The colonization of Australia is another example of the same kind of migration in modern times: for though there were tribes of aborigines wandering over the vast districts of that large island, yet they were so few, so widely scattered, and of so low a type and civilization, that the country may be considered to have been practically unoccupied.

The second class of migrations, viz.:—those into countries already occupied, may be classified according to the dominant motives which influenced them, and the principles which governed them:—

1st. Military.
2nd. Religious.
3rd. Commercial.
4th. For this class it is difficult to find a name which shall exactly express the idea; they may be called agricultural, or colonial, being influenced by the desire to acquire land, to till it—"earth hunger" as it has been called.
5th. Those of a mixed class, which can scarcely be reckoned with either of the other classes, being caused by a compound of two or more of the motives influencing the former classes.

1st. Military migrations: those in which acquisition of territory or increased dominion is the governing principle. Of this class we have an example in the movement at present going on in Central Asia, where Russia is seeking to extend her territory, and to obtain possession of large tracts of land in Bokhara and Turkestan, even extending her conquests to Khiva. This is merely for the sake of conquest, said to be caused by a disturbed frontier, and the necessity of preserving peace on the borders of the empire. Here there is a tolerably numerous population, and this region has frequently been overrun in a similar manner before. These migrations have not greatly affected the blood, though their political effects are evident. The race inhabiting the greater part of these regions is still mainly

Aryan, speaking a dialect of Persian. South Africa furnishes examples of this kind of migrations. The Caffres are a great conquering people, and are constantly making incursions on their neighbours. Dr. Kirk gives an instance of a large tribe using the Caffre mode of fighting, and in many of their customs resembling them, yet evidently not of Caffre race. The explanation is this. A certain tribe of Caffres went forth some years ago on a conquering expedition, and completely destroyed all the adults of the tribes they attacked, preserving all the children; these they carefully trained in their own customs, language, and manner of fighting, which they have still retained long after their Caffre conquerors have died out, and left no trace.

The incursions of the Germanic tribes at the downfall of the Roman Empire is another instance of military migration. It is probable that they were not nearly so numerous as is generally supposed. Germany at the time was not nearly so thickly peopled as at present; much land was unoccupied, being either waste or forest. It is most likely small bodies of these men invaded the Roman provinces. Even the Franks, who overran Gaul, and gave to the country their name, were probably very few in number, and most likely could be counted by tens of thousands. These, though affecting the country politically, have left little trace in the blood of the people, unless in the north-east. The Frenchman of to-day is but little different in character from the Gaul described by Cato and Cæsar, having but little of the German element either in his character or language: lively, restless, given to war, and fond of talking. The occupation of Italy by the Normans was a military migration, though of a somewhat different character from those already mentioned, The Normans went thither a few at a time, by twos and threes, and uniting when there, conquered the country. These have left no trace, as far as I am aware, in the blood, language, or manners of the people.

Of the second class, or religious migrations, though formerly numerous and important, we have at the present time only one example,—that now going on in Central Africa, where the Arab and Berber tribes of the north are pushing southward into Soudan, and converting the negro tribes of that country to the Mahometan religion, which, being superior to the Fetishism of the natives, makes itself felt in the elevation of the negro type. Mahometanism there is certainly not dying out, as some have supposed it to be, and as it is in other parts, where it is in contact with a superior religion. The whole history of Mahometanism shows it to be throughout a military migration. Animated by a desire for conquest to spread the religion, the Arabs penetrated into distant countries, and Arab arms carried their religion to the Oxus and the Indus, and through North Africa to the Atlantic, Spain, Italy, and various parts of Europe, and it is said that traces of Arab blood can even now be discovered in Canton Valais.

Among these may be placed the Crusades, which were in the contrary direction. Ethnically, they were of but little importance. Very little Frankish blood can now be found in Syria. Their effects were chiefly moral. The expulsion of the Moors from Spain by Ferdinand and Isabella is an instance of forced religious migration. Similar to this, was the departure of the Huguenots from France, though their departure was more voluntary than otherwise, as the French government did all in its power to retain them, and placed all possible obstacles in the way to prevent their going. Immense numbers left their homes, for England, Holland, and Germany. Smiles says that from Normandy alone there were 184,000 refugees. Though these numbers are probably exaggerated, yet the movement was a very important one, socially and morally, and many effects of their immigration still remain. Little marked effect, however, has been left on the national type, and, except in Spitalfields, their descendants can scarcely be traced.

The third class consists of those movements of large bodies of men, who settle in foreign countries for commercial purposes. Such are our trading settlements in China and Japan in the present day. Such were formerly the trading colonies of the Phœnicians on the Mediterranean, and even in Cornwall. The Jews furnish another instance of this kind of migration. Though their movements were frequently caused by persecution, yet the principal motive which influenced them was commercial. They seem always to have kept on the frontier line of civilization: their character being peculiarly adapted for commerce, they have been able to penetrate where others dare not venture. Thus they existed in former ages in large numbers in the towns on the Rhine, as now in Cape Colony and Caffraria. This accounts for the presence of so many Jews in East Germany, Poland, and Russia. The ethnological effects of such migrations are in some cases considerable, in others very slight. Commercial settlements were made during the middle ages by the Genoese in the Levant and Asia Minor, and the remembrance of this is so strong in the minds of the Turks, that if asked concerning any old building of doubtful origin, they will surely answer, "It is Genoese." To this class belongs the occupation of the West Indies by Europeans for commercial purposes. This is not likely to be permanent, as the climate is not suited to the European constitution. Amongst this class must be reckoned the introduction of the Negro race to America, which, though not spontaneous, has been productive of great ethnic results. There the black race has thriven. In St. Domingo the Negroes predominate; also in the southern United States, as Louisiana, Florida, and the lower parts of Georgia and South Carolina. The climate suits them, and does not suit those of European descent; and it is most probable the Negro race will always predominate in some of those States.

Of the fourth class of migrations, the best example is afforded by those of our own race to the United States and New Zealand. In the first case, in spite of opposition from a powerful race, which, though our inferiors, was sufficiently strong to offer considerable resistance, as they still are doing, and no doubt will continue to do until they are "improved off the face of the earth." Such a migration took place in China, when two thousand years ago the Chinese, a hardy, prolific race, came in immense numbers from the sterile plains in the north-east into the valleys and rich alluvial plains of China. They now occupy the best parts of the country, and are to the original inhabitants in the proportion of ten to one. The Aborigines are much more numerous in the mountains, whither they were driven by the invaders. To this class belongs the occupation of Hindoostan by an Aryan race. Five hundred years before the Christian era, impelled by "earth hunger," they entered the Punjaub, crossed the Indus, and settled in the fertile plains of India. Perhaps they were not much superior to the previous inhabitants in military prowess and manners, yet they spread themselves over the country, either by moral or religious superiority. In India, the farther north the more Aryan is the type. In the south the people are darker and of less marked Aryan character, though possibly much of this is due more to difference of climate and other causes than to any great original difference of race. The migrations to further India were probably owing to the religious idea, for there, we are told, are to be found in the jungle temples worthy to be named in the same breath with the cathedrals of Europe. But of these migrations all traces have died out, either because the climate was unsuitable, or because, as Buckle says, "The forces of nature were too much for savage man." The Saxon invasion of England must be named in this class, for though accomplished by force, it was not essentially military, but an expedition to get land to till, and the names the Saxons gave to their settlements prove this. They wanted more room than would be found in the little countries from which they came,—Sleswick Holstein, and Friesland. Simply military migrations would scarcely have influenced the language, type, and character as they have done.

To the fifth class belong the occupation of the ports on the south of Ireland by the Oestmen or Danes. A party of them, sailing up the R. Suir, founded a city, which they called Waterford, and from thence traded to the West of England. Probably the existence of Bristol as a port, is owing to them, for they established a trade with it in various commodities, principally in slaves. The effects of this settlement are clearly traceable at the present time, for most of the inhabitants of Waterford and the immediate neighbourhood are of the Danish or Norse type, with fair hair and light complexion, while in the hills, at only a short distance, are to be found the true Irish, with bluish grey eyes and dark hair. To this mixed class belongs also the colonization of America by the Spaniards. This was of great importance politically, but their numbers though large were not sufficient to make them predominate ultimately, except perhaps in Chili. The irruption into Europe of the nomadic races of Central Asia was of great ethnic importance, but its effect was not to advance the improvement of the human race, but to retard it.

These tribes have greatly changed the lines of races. In the ninth century, the central plain of Hungary was occupied by the Magyars, who came with their wives and children, and destroyed, thrust out, or enslaved all the previous inhabitants. The Hungarians are even now very un-European in their appearance. In a similar manner, the Turks have occupied countries. Only in Asia Minor are the cultivators of the land of the same blood as the dominant race. In all other parts of Turkey, the Turks live chiefly in scattered garrison towns, while the agriculturists are of another race.

Of the various causes which influence the permanence or decadence of migrating nations, the principal one is climate. If the climate is unsuited to the migrating nation, the consequence will be decadence.

The Germans could not retain Italy because, though morally they might have kept it, physically they could not. Italy does not suit the German constitution. Even in Lombardy, where they settled in great numbers, very little of the German element is left. Our settlements in India are not likely to prove permanent for the same reason, we cannot stand the climate. It may be said, "How then did the Aryan race at present inhabiting India obtain a permanent footing there?" It is probable they came in at the north where it is much colder than in the other parts, first inhabiting the Punjaub, a country of hot summers and cold winters, not so very different from the country they left, they thus in the course of centuries became acclimatised, their constitution altering slowly. We, on the contrary, inhabit a country totally different in climate to even the cooler parts of India. The permanence of migrating races is secured by the admixture of both sexes. This accounts for the want of permanence generally characterizing military migrations, there being in them so few females, and the fighting sex predominating. Children adopt the language and manners of their mothers, much more readily than those of their fathers. In Normandy the Norsemen soon forgot their their own language and took to Norman French, and long before the Norman Invasion of England, the nobles who wished their children to be not entirely ignorant of the language of their northern ancestors, were accustomed to send them to Bayeux, where Norse or a kindred dialect was spoken. The reason why Bayeux retained this dialect so long was that a large number of Saxons of both sexes had been settled thereabout as colonists in previous centuries.

Museum Notes—Dundry Gasteropoda.

BY E. B. TAWNEY, F.G.S., Assoc. R. Sch. Mines.

(Read before the Geological Section, March 12*th,* 1873.*)*

THE present communication is the result of an examination of the Dundry Gasteropoda in the Bristol Museum. It is offered to the Society as a small contribution to the knowledge of the fossils of one of the rich localities in our neighbourhood. At the same time, we would consider it merely a preliminary report, and as the materials are derived mainly from one collection, we put it forward rather as an aid and stimulus to future work than as a complete list.

We should be extremely glad if collectors would kindly let us see any specimens that seem either new, or particularly well preserved. We beg to offer our thanks to Mr. Stoddart, F.G.S., for access to his collection.

If we turn to the description of the Dundry beds given by Mr. Etheridge, F.R.S.,* we find that his list of Dundry Gasteropoda

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* Appendix to Dr. Wright's admirable Paper on the Inferior Oolite in the South of England.—Quarterly Jour. Geol. Soc. XVI. p. 21, 1859.

obtained by the collation of three collections, amounts to only eighteen species, of which two were undetermined, viz:—

Cirrus nodosus
.... Leachii
Littorina ornata
.... sp.
Nerinea anglica
Pleurotomaria ornata
.... abbreviata
.... elongata
.... fasciata
Pleurotomaria armata
.... punctata
.... sulcata
.... proteus
Monodonta lævigata
Alaria Phillipsii
Chemnitzia lineata
Turbo Milleri
Trochus sp.

Two of these we shall see must be merged into one, so that the total remaining will be seventeen species.

Our own results differ somewhat widely from this. From our own Museum we obtain a total of sixty-six species in a determinable condition, besides casts and imperfect fragments of shells. Of the genus Pleurotomaria alone there are twenty-six species.

The total is more than double those in the catalogue of the Museum of Practical Geology, and which are drawn from the whole kingdom.

We may therefore call our Museum rich in Inferior Oolite Gasteropoda. Dr. Wright (loc. cit.) gives a much fuller list however, viz., forty species from Somersetshire, besides three or four from other localities. This tallies much better with the result of our examination.

Quenstedt (Jura, p. 414) has lamented the number of species which D'Orbigny makes in the genus Pleurotomaria. Though anxiously on the look out for transitional forms, which would enable us to unite under one species what had before been kept separate, we are bound to say our opinion is, from a comparison of Dundry specimens, that the greater number of D'Orbigny's species must be upheld for the present. If it be said that he goes too much into minutiæ of surface ornament and so on, we must rejoin that a neglect of similar details among recent Mollusca would prevent us separating what we know from the study of the soft parts, to be the shells of different species. It is their fortunate fine preservation which alone made such a detail analysis possible. The German palæontologist seems not to have had well-preserved specimens under his hands.

Out of our total of sixty-six species determined, we take nineteen to have been hitherto unfigured; besides these, the following fifteen do not seem to have been cited before in British lists.

Natica Zelima, D'Orb.
Nerinæa bacillus, D'Orb.
Alaria Perrieri, Piette.
.... Lorieri, D'Orb.
.... Lotharingica, Schlumb.
Trochus Zetes, D'Orb.
.... Niortensis, D'Orb.

Littorina ædilis, Muen.
Pleurotomaria Amyntas, D'Orb.
.... Allica, D'Orb.
.... monticulus, Desl.
.... reticulata, D'Orb.
.... Sauzeana, D'Orb.
.... Agatha, D'Orb.
.... subdecorata, Muen?

We now add a detail enumeration, with critical notes on some of the species. The number of specimens on which each determination is based has been given. From the scarcity of material, many determinations are open to doubt, and must only be received provisionally.

The length of the axis of the shell is often given, the breadth being measured along a plane at right angles to this. The angle of the spire is sometimes added, for the sake of comparison with D'Orbigny's descriptions, but it is impossible to take it where the outline is curved—and in most cases it is an uncertain measurement. The unit of length used is the millimetre.

PURPURINA BELLONA, D'Orbigny. Pl. 3, fig. 8.

1850 Purpurina Bellona, D'Orb. Pal. fr. Terr. Jur. 2 Gast. pl. 331, figs. 1—3.
Syn? 1858 Turbo serratus, Qu. Jura. p. 485, tab. 65, fig. 7.
...... 1860 Purpurina Orbignyana, Heb. and Desl. Bull. Soc. Linn. Norm. V. pl. 1, fig. 6, p. 176.

Our specimen is intermediate between the descriptions of the first two authors cited. It has the more distant costæ of the German specimen, but the more marked longitudinal ridges and the narrow open umbilicus of the French. Quenstedt deemed the distance between the costæ sufficient to distinguish his species. We should like further evidence on this point. We have, unfortunately, only one specimen. In the mean time we adopt the older name. At any rate, we cannot allow that *P. Orbignyana* should be separated because of its smaller size and sharper ribs merely. It is probaby a dwarfed descendant of the Inferior Oolite shell.

We have a single specimen only.

Locality—Dundry. *Inf: Ool.*

It has been cited by Dr. Wright from Somersetshire, (loc. cit. p. 37.)

PURPURINA INFLATA, n. sp. Pl. 3, fig. 9.

Height 32 mm. Breadth 27 mm.

Shell subglobose, spire depressed: whorls rounded, with a flattened space at the suture, forming an angle with the rest of the whorl. Last whorl inflated, with numerous transverse rounded costæ, which are prominent at the angle, but gradually fade away towards the base. Numerous fine longitudinal ridges: umbilicus probably closed.

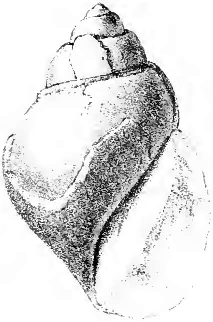
We have considerable reluctance in making a new species. We have tried to identify it with *P. Coronata*, Heb. and Desl. (Bull. Soc. Linn. de Norm. V. pl. 1, fig. 6), but it is more globose, the costæ more oblique, longitudinal lines more numerous, &c. Moreover the French authors consider the Inferior Oolite forms distinct from their species.

We have only two specimens.

Locality—Dundry. *Inf: Ool.*

1a.

1b.



2a.

3.

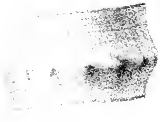
4a.

4b.

2b.

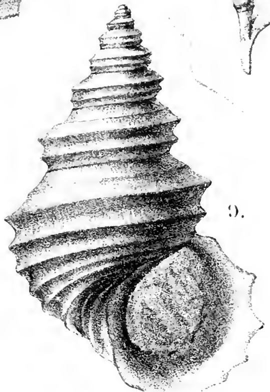
5a.

5b.



6.

9.



7.

8.

G.H Ford & C.L Griesbach.

Mintern Bros imp.

NATICA.

We have numerous specimens, which we are disposed to group under four species. In the state of synonymy it is uncertain what names these should bear; the present attempt to characterise these without an opportunity of examining foreign types especially is put forward merely as an attempt.

With respect to the genus, it has long been suggested by Herbert, Deslongchamps, Laube, &c., that these elongate forms should be placed apart. We therefore follow Morris and Lycett in placing them under *Euspira* Ag. It will be observed that all our forms have a canal or flat ledge at the suture, and most have a punctate shell. This latter character alone should remove them from Natica, and we should be disposed either to limit Euspira to those species with a punctate test, or to create a new genus for them; perhaps the word *Naticapora* might do for such.

EUSPIRA BAJOCENSIS, D'Orb. Pl. 1, figs. 2 and 4.

1847 N. Bajocensis, D'Orb., Prodr. I., p 264.
1850 .... D'Orb., Pal. fr. Terr. Jur. 2 Gast., pl. 289, f. 1, 3, p. 189.
Syn. 1850 N. Pictaviensis, D'Orb., Pal. fr. Terr. Jur. 2 Gast. pl. 289, f. 8—10, p. 191.
1866 N. Crythea, Laube, Gast. d. br. Jura, v. Balin. pl. 1, fig. 6.

Length 34 mm. Breadth 24 mm.

We have so many intermediate forms that we feel obliged to group together shells which apparently differ so much in shape as figs. 2 and 4 of our plate. The angle of the spire varies between 60 and 70 degrees. The test is regularly punctate. The punctæ are set in regular rows at equal distances, but are by no means always preserved—for instance, they do not happen to be seen in the individual figured, (fig. 2) though well shown on another evidently the same size and shape, as well as in our fig 4, and others of intermediate size. As this punctation is not described by the French author, it is perhaps hazardous to refer our shells to the foreign type. It is preferable however to forming a new name uselessly. Shells agreeing with our fig. 4 are named in the Museum of the Geological Survey as *N. punctura*, Bean; these belonged apparently to Dr. Lycett's collection. They do not disagree perhaps with the cut given by Bean of his shell (Ann. Mag. Nat. Hist., 1839, III., p. 62), but he makes no mention of punctæ. I cannot, however, imagine them to be the same as the shell figured by Lycett and Morris (Great Ool. Moll. pl. 15, fig. 18); their figure wants the separation of the whorls by the flat ledge at the sutures, though the description agrees in some other points. Those who have access to the originals must decide.

Some may be disposed to make two varieties in this species. The larger form (fig. 2) corresponds in shape with *N. Pictaviensis* D'Orb., but it is encircled with several spiral lines, at unequal distances, which give an obscurely polygonal aspect to the last whorl especially. The flat space at the sutures is almost plane, scarcely excavate. The smaller form (fig. 4) has the spire more acute. The whorls seem to be free from the spiral prominent lines, and the suture is a little more hollowed out like a canal, instead of being flat.

Oppel cites *N. Pictaviensis* from Burton Bradstock, (Jura., p. 384). Remains of epidermal colour remain in both our figured specimens, as transverse bands, alternately light and dark.

There are fifteen specimens in the Museum, with the shell more or less preserved, besides numerous internal casts.

Locality—Dundry. *Inf: Ool.*

EUSPIRA ZELIMA, D'Orb.? Pl. 1, fig. 1.

1850 Natica Zelima, D'Orb. Pal. fr., Terr. Jur. 2 Gast. pl. 290, fig. 8.

Height 41 mm. Breadth 26 mm.

We have one specimen which corresponds in shape to the cast of the shell figured by D'Orbigny.

The whorls are more swollen than in *N. Bajocensis*, and they meet at the suture in a way that disposes me to rank it as a different species; they round off more into one another, though the suture is marked by a wide flat ledge. Moreover the shell has a somewhat blunter form towards the apex, though the spire is much produced.

The umbilicus seems to be closed by the growth of the inner lip.

There is only one specimen in the Museum, so that the identification is provisional only. It was described originally from the Great Oolite.

Locality—Dundry. *Inf: Ool.*

EUSPIRA DUNDRIENSIS, n. sp. Pl. 1, fig. 3.

Length, 34 mm. Breadth, 27 mm.

Shell globose, spire somewhat elevate, apex acute: whorls six, obtusely rounded, separated by a broad flat space at the suture, but rounded at the angle. Last whorl swollen. Surface of shell with numerous very fine transverse lines, and a few distant obscure spiral raised lines. The test is punctate: punctæ in equidistant rows. There is no umbilicus visible, the lip seems expanded over it.

There are in the Museum four specimens.

Locality—Dundry. *Inf. Ool.*

EUSPIRA CANALICULATA, Lyc. and Morris.

1854. E. canaliculata. L. and M. G. Ool. Moll. Univalves, pl. 11, fig. 23, p. 45.

The specimens which we place here agree with the figure in Lycett's "Handbook to the Cotteswolds," (pl. 3, fig. 10.) Owing to a mis-print, we are ignorant what is there represented, but we take it to be this species.

There is a very broad flat space at the sutures. The shell is not preserved, so we cannot say whether it be punctate.

There are in the Museum two specimens.

Locality—Dundry. *Inf. Ool.*

CHEMNITZIA LINEATA, Sowerby.

1818. Melania lineata, Sow. Min. Conch., pl. 218, fig. 1, p. 33.
1850. Chemnitzia lineata, D'Orb. Pal. fr. Terr. Jur. pl. 239, figs. 4, 5, p. 43.
Syn? 1842. Melania procera var. b. Desl. Mem. Soc. Linn. Norm. VII., pl. 12. fig. 6, p. 223.

This is a very variable shell, and approaches very nearly to the next species in some cases, though it is easy to find specimens differing widely therefrom, and agreeing exactly with Sowerby's figure.

The chief characteristic I take to be the lines of punctæ arranged spirally, (not transversely across the whorls as might be supposed from Sowerby's figure); this alone perhaps enables one to distinguish it from the next species, for the whorls are often separated by a depression formed by the bevilling of each whorl at the suture.

Deslongchamps (loc. cit p. 224) in founding his species *C. procera*, says he thinks his var. b. may be the same as the present species; I think it very probable.

There are over a dozen specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

We have it also from the Upper Lias of the Yeovil district.

CHEMNITZIA PROCERA, Deslongchamps.

1842. Melania procera, Desl. Mem. Soc. Linn. Norm. VII. pl. 12, fig. 5. (non 6.)
1850. Chemnitzia procera, D'Orb., Pal. fr. Terr. Jur. 2. Gast. pl. 239, figs. 2, 3, p. 41.

Syn? 1842 Melania coarctata, Desl. Mem. Soc. Linn. Norm. VII. pl. 12, fig. 13, p. 227.

Syn? 1854 Chemnitzia coarctata, D'Orb, Pal. fr. Terr. jur. 2 pl. 240, fig. 1—3.

Length, 65—85 mm.

It appears almost hopeless, as Deslongchamps says, to attempt specific divisions to this genus. However, under the above name I would include a group of forms characterized by the wider sutures in the older whorls, each whorl being depressed at the junction; by more wavy lines of growth, and tendency to incipient tubercles on the last whorl. But all of these characters vary so in different individuals, and even in younger and older parts of the same specimen, that the only character I find left to rely upon in distinguishing it from the preceding species is the absence of punctæ.

None of our shells show the epidermal colours. I should look upon these as most important, and doubt D'Orbigny being right in joining *C. turris* to *C. coarctata*, Desl.

There are six specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

CHEMNITZIA HEDDINGTONENSIS, Sowerby.

1813 Melania Heddingtonensis, Sow. Min. Conch. pl. 39, outer figures.

1850 Chemnitzia Heddingtonensis, D'Orb. Pal. fr. Terr. jur. 2. pl. 244, p. 56.

A specimen which would be six inches long if complete, cannot be distinguished from Coralline Oolite forms. We therefore place it under this name: for to restrict the appellation to forms found in the Coralline Oolite alone, would seem to us to be reasoning in a vicious circle.

Deslongchamps cites it also from the Inf. Oolite. Professor Phillips cites it from White Nab, (I. Ool.?) Seebach (Hann. Jura., p. 31) cites it from the A. opalinus zone of the Lias.

We have only one specimen.

Locality—Dundry, *Inf. Ool.*

NERINÆA BACILLUS, D'Orbigny.

N. bacillus, D'Orbigny. Pal. fr. Terr. Jur. 2. pl. 252, figs. 3-6.

Three specimens occurring in one block are referred to this species provisionally, the identification being uncertain. These specimens are elongate as in the type; they have spiral lines, as in fig. 5, but not the transverse; there is a fine double ridge at the suture, *i.e.* one on each side. The columella is unseen. D'Orbigny cites it from Great Oolite—Laube cites it from Balin, with many Inferior Oolite forms.

The locality is not certain, but we imagine it to be Dundry.

Inf. Ool.

NERINEA FUNICULUS, Deslongchamps.

1843 N. funiculus, Deslongchamps. Mem. Soc. Linn. de Norm. VII. pl. 8, figs. 30—32, p. 186.

1850 N. funicolosa, D'Orbigny, Pal. fr. Terr. Jur. 2, pl. 252, figs. 7—10.

1850 N. funiculus, Morris and Lycett. Gt. Ool. Moll. pl. 7, f. 12,

Our examples taper rather more rapidly than the typical form. The whorls are adorned with longitudinal lines, two of which bear minute tubercles. Mouth angular; columella with at least one fold near the apical end, and apparently another near the lower end of the mouth.

There is a block with five imperfect specimens, of which the above is a short description. The identification is uncertain.

This specimen is not labelled, so the locality is uncertain; therefore, whether it is Inferior Oolite is not known with certainty.

MELANIA UNDULATA, Deslongchamps.

1843 M. undulata, Deslongchamps. Mem. Soc. Linn. de Norm. VII., pl. 11, fig. 58—62 (non Chem. undulata, D'Orb., Pal. fr. Terr. Jur. 2, pl. 237, figs. 16, 17. nec Stoliczka, Sitzungsb. Wien. Ak. XLIII. tab. 1, fig. 1—1861.)

Syn. 1858 Cerithium muricatum, Quenstedt. Jura. tab. 57, fig. 17, (? Sow)

In the face of much division of opinion, I am uncertain as to the name to be given to this shell. Our shell is very much like *C muricatum*, Sow., but the mouth seems narrower; unfortunately it is imperfect here; the character of the mouth I take to be the only distinction between *Turritella muricata*, Sow., and *Melania undulata*, Desl.

They have been united by Laube, but this is not approved by Dr. Brauns.

We have a small block, with six specimens.

Locality—Dundry. *Inf. Ool.*

ALARIA MYURUS, Deslongchamps.

1842	Rostellaria myurus,	Desl. Mem. Soc. Linn. de Norm. VII. pl. 9, figs. 23—25, p. 176.
1850	Pterocera	D'Orb. Pal. fr. Terr. Jur. 2, pl. 430, figs. 6—8.
1863	Alaria	Lycett, Gt. Ool. Mol. Suppl. p. 122.
1864	....	Piette. Pal. fr. Terr. Jur. 3, Gast. pl. 2, figs. 8—11. p. 30.

There can be little doubt about the occurrence of this shell at Dundry. It is ornamented with regular spiral lines, and some much fainter transverse lines. The two oldest whorls have two strong keels, but the young whorls are not sharply keeled like the old ones. There is a thickening on the columella in one of our specimens. The spines are perfect in none, but the spine on the back of the whorl has left a projection on the internal mould.

There are six specimens in the Museum.

Locality—-Dundry. *Inf: Ool.*

ALARIA DUNDRIENSIS, n. sp. Pl. 1, fig 5.

Shell fusiform, elongate; whorls 7-9 angular: the keel not quite in the middle of the whorl, but inferior thereto; on the keel is a series of tubercles, probably 12—14 on a whorl, which do not form costæ in the older whorls, *i. e.* the three last, but are vertically compressed; the surface shows faint transverse lines; there are fine longitudinal lines, which are stronger near the suture.

The character of the keel and tubercles distinguish it from *A. hamus*, Desl., and *A. sulcicostata*, Piette.

We have three specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

ALARIA TRINITATIS, n. sp. Pl. 1, fig. 6.

The materials for this species are very imperfect, but it cannot be identified with any previously described.

The shell is very acute; whorls angular, about 8 in number; the keel is very near the inferior edge of the whorl, and not parallel to the suture; this is the most marked feature of the shell—it is caused by a spine apparently on the keel at the same place, in successive whorls, so that there is sometimes an appearance of a ridge all down the shell. On the last whorl of one specimen are seen two spines, one below the other, the upper one stronger. The surface is ornamented with fine longitudinal lines, and somewhat stronger wavy transverse ones.

It is much more acute than *Alaria longispina*, Desl. sp., and the position of the keel would distinguish it.

There are eight specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

ALARIA PERRIERI, Piette.

1864 Alaria? Perrieri, Piette, Pal. fr. Terr. Jur. 3, Gast. pl. 1, figs. 10, 11, p. 28.

We do not put forward this identification as more than provisional. Our shell has markings more like a Fusus than the other species, viz., strong transverse costæ, which are crossed by raised longitudinal lines. Columella straight, as far as that part of it which is preserved is concerned. No spines seen.

We have only two specimens, both fragmentary.

Locality—Dundry. *Inf. Ool.*

ALARIA LORIERI, D'Orbigny.

1847 Pterocera Lorieri, D'Orb., Prodrome I., p. 270.

1850 .... D'Orb., Pal. fr. Terr. Jur. 2 Gast., pl. 429, figs. 7—10.

1864 Alaria .... Piette, Pal. fr. Terr. Jur. 3 Gast., pl. 2, figs. 12—14, and pl. 4, figs. 1—3, p. 32.

Whorls with an acute keel; there are numerous strong spiral or longitudinal lines, which become a little less close together near the suture: the last whorl has two keels; the whorls meet with a circular sweep, the continuity of which is scarcely broken by the suture. Our specimen does not show the entire columella, but it would seem to be straight. It is chiefly the character of the ornamentation, agreeing as it does with the drawings of M. Piette, which induces us to place it here.

There is only one specimen in the Museum.

Locality—Dundry. *Inf. Ool.*

ALARIA ETHERIDGII, n. sp. Pl. 1, fig. 7.

Shell acute, whorls apparently 8—9, angular, ornamented with regular longitudinal lines; keel much elevated, sharp on all the whorls; the last whorl has two keels. Suture deeply impressed. At the suture is a beaded band, which is plainest in the younger whorls (too fine to be shown in the figure unmagnified). The columella is not seen.

This species, I regret to say, is founded on a single specimen, but the band near the suture sufficiently distinguishes it as a distinct form.

Locality—Yeovil. *Inf. Ool.*

ALARIA, sp. Pl. 1, fig. 8.

An imperfect specimen, showing only one keel on the last whorl, we may place provisionally in this genus.

The other whorls are smooth, all are ornamented, with regular spiral lines.

We merely figure it in order to induce others to collect materials for its identification.

Locality—Dundry. *Inf. Ool.*

ALARIA LOTHARINGICA, Schlumberger.

1864 A. Lotharingica, Schlumberger, Bull. Soc. Linn. de Norm. ix. p. 222, pl. 6, figs. 1—3.
1867 ………………… Piette, Pal. fr. T. Jur. 3. Gast., p. 105, pl. 21, figs. 1—11.

Length, if complete, 40—45 mm.

Shell acute, spire of numerous whorls, which are angular near the upper part, *i.e.*, there is a shoulder giving a turreted form; the whorls are crossed by strong rounded transverse costæ and finer longitudinal lines; the keel on the last whorl is sharp.

Our specimen is imperfect and shows no spines, nor any wing; still the part of the mouth and columella which is preserved points to its being an Alaria, while the shape of the whorls and the ornamentation agrees with the foreign type, as far as we may judge from descriptions.

It is said to be common near Nancy, in the Murchisoni and Sowerbyi zones.

We have only one specimen.

Locality—Dundry. *Inf. Ool.*

LITTORINA ÆDILIS, Muenster.

1844 Turbo ædilis, Muenster. Goldf. Petr. Germ. tab. 194, fig. 9.
1864 .... Seebach. Hann. Jura. p. 47.
1869 .... Brauns. Mittel-Jura. p. 180.

Length, 13 mm.

Shell acute; whorls six, with three longitudinal elevated bands, crossed by numerous sharp transverse costæ, which rise into tubercles where these cross.

Our shell agrees with the description of the type, except that ours is more regularly conical, but we do not consider this an important difference, as the ornamentation appears precisely the same.

We prefer to place it under the genus Littorina.

There are four specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

It is cited by Seebach, as well as by Brauns, from the Oxfordian beds of N. Germany.

LITTORINA BIARMATA, Muenster.

1844 Trochus biarmatus, Muenster. Goldf. Petr. Germ. tab. 180, fig. 2.
1858 Trochus monilitectus, Oppel. Juraf. p. 385. (non Phillips, nec Morr. & Lycett.)
1858 .... Quenstedt. Jura. tab. 57, figs. 3, 4, p. 416.
1869 .... Brauns. Mittel-Jura, p. 182

Length 13 mm.

Our specimens, which are well preserved, agree exactly with Goldfuss' delineation. There are three bands on each whorl, the middle one not half-way between the others, but closer to the inferior one; these bands are crossed by sharp elevated costæ, oblique in direction, which rise into tubercles at the place of crossing.

I cannot follow Oppel or Dr. Brauns in identifying this shell with *T. monilitectus*, Phillips. From the character of the mouth I prefer to place it in the genus Littorina.

We have four specimens.

Locality—Dundry. *Inf. Ool.*

LITTORINA RECTE-PLANATA, n. sp. Pl. 2, fig. 6.

Length 13 mm. Greatest breadth, 9 mm.

Shell conical, acute. Whorls straight-sided, separated by deeply-impressed sutures, and ornamented with four elevated bands, which are somewhat tubercular. The intervals between the bands are crossed by numerous strong, oblique, curved lines; these extend also, and are still more pronounced between the sutures and the nearest bends.

The last whorl is subangular; there are four ridges above the angle, the base is convex, and has five ridges. The mouth is trapezoidal.

Our single specimen is rather rubbed, so that the ornaments of the surface are not sharply preserved.

Locality—Dundry. *Inf. Ool.*

NERITOPSIS BAJOCENSIS, D'Orbigny.

1847 N. Bajocensis, D'Orbigny. Prodrome I. p. 264.
1850 .... D'Orbigny. Pal. fr. Terr. Jur. 2, Gast. pl. 300, figs. 8—10, p. 223.
1867 .... Laube. Gast. d. br. Jura v. Balin. tab. 1, fig. 9.

Notwithstanding that our specimens are very imperfect, we refer them pretty confidently to this species—though in the state of moulds chiefly, there is enough of the shell left on the upper whorls to enable us to identify them.

It was described by D'Orbigny from the Inferior Oolite of Calvados; subsequently it was cited by Dr. Wright from Somersetshire, from the same horizon; again, by Dr. Laube, from Swinitza and Balin.

There are three specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PHASIANELLA STRIATA, Sowerby.

1814 Melania striata, Sowerby. Min. Conch. pl. 47, (non P. striata, J. Sow. in Fitton. Geol. Trans. 2 Ser. IV. tab. 18, fig. 15.)
1858 P. Sæmanni, Oppel. Jura. p. 387.
1860 Chemnitzia Sæmanni, Wright. Q. J. G. Soc. XVI. p. 19.

On comparison of specimens from the Inferior and Coralline Oolites, I cannot find any valid distinction. Oppel's idea as to the breadth of the bands being greater in the early form seems to me not to hold good.

This species in that case has the same range as *C. Heddingtonensis*, Sow.; as both these are widely spread geographically, we need not be astonished at their vertical range.

Locality—Cleeve Hill, near Cheltenham. *Inf. Ool.*

Though we have no specimens from Dundry, we have noted this species here. We would not give undue weight to dubious zoological distinctions for the sake of rounding a geological system.

AMBERLEYA PRINCEPS, Rœmer.

1836 T. princeps, Rœmer. Ool. Geb. p. 153, tab. 11, fig. 1.
1844 .... Goldf. Petr. Germ. tab. 195, fig. 2.
1850 .... D'Orbigny. Terr. Jur. 2 Gast. pl. 335, figs. 9, 10, p. 357.
Syn? 1860 Eucyclus pinguis, Desl. Bull. Soc. Linn. de Norm. V. p. 145, pl. 11, fig. 7.

We found a specimen of this shell, in company with Mr W. S. Mitchell, in a roadside section, west of Midford, near Bath.

Imperfect as it is, it agrees perfectly with the description of the authors cited, though they give the Coralline Oolite as its position.

Deslongchamps has apparently been led by mere accidents of fossilisation in making a separate species for the Inferior Oolite form.

Our single specimen is from the inferior Oolite, not far above the "Midford Sands." It would thus seem to have a considerable range.

One specimen only.

Locality—Midford. *Inf. Ool.*

AMBERLEYA ORNATA, Sowerby. (non D'Orb. nec Goldf.) Pl. 1, fig. 9.

1819 Turbo ornatus, Sow. Min. Conch. pl. 247, figs. 1, 2. (Littorina in Index to ditto.)
1860 Eucyclus .... Desl. Bull. Soc. Linn. de Norm. V. p. 140.
Syn? 1844 Turbo capitaneus, Muenster. Goldf. Petr. Germ. tab. 194, fig. 1.
..... 1850 .... D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 329, figs. 7, 8.
...... 1844 .... spinulosus, Mu. Goldf. Petr. Germ. tab. 194. fig. 3.
.. .. 1850 Purpurina Bathis, D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 330, figs. 6—8.
...... 1867 Amberleya capitanea, Moore. Somerset Nat. His. Soc. Proc. XIII. pl. 6, figs. 1—5.

From an examination of Dundry specimens compared with Goldfuss' figures, it appears to me that *T. capitaneus*, Mu. cannot be separated from *Littorina ornata*, Sow. I have therefore ventured to unite them.

The original specimens of the Mineral Conch. ought to be in the Bristol Museum, but they are unfortunately missing. Judging however from such specimens as we have—compared with Sowerby's figures, I should say that Goldfuss and D'Orbigny are mistaken in their identification of this species. I take *Purpurina Bathis* to be identical with the specimen which we figure; the aperture of the French type is probably a bad restoration. If D'Orbigny's drawing of *P. ornata* is faithful, it represents probably a different species.

Those of our specimens which are worn or imperfectly preserved present an appearance like the upper ones of Sowerby's plate; the aperture of his figure 2 would be probably identical in shape with that of our figure, and is quite unlike any of the Continental descriptions, which may be restorations of imperfect specimens. The absence of the little sharp tubercles or spines on the ridges is an accident of fossilisation probably. Though absent in our figured specimen, they are well seen on another, which is plainly and unmistakeably identical with it.

The characteristic distinction of this species then we take to be the greater size and prominence of two of the ridges on the middle of the whorl, which leave an impression on the mould.

Below these on the last whorl are 4—5 others; all bear small spines at intervals. The aperture when preserved is round with an outline like the section of a fluted column.

T. capitaneus, Mu. seems to differ at first sight by the absence of a ridge between the larger ones and the suture, but it is doubtful whether this is a constant character, for it is absent in one of our specimens on the last, but not on the other whorls. It seems to me that *T. spinulosus* is merely a synonym of this species. If *T. capitaneus* and *spinulosus* are really distinct species, then Sowerby's appellation should fall to the ground, for it includes both. It is a pity that his figures are so imperfect.

Oppel cited *T. capitaneus* from Frocester Hill, (Juraf. p. 386,) but not *Littorina ornata*. He notices however *P. Belia*, D'Orb., from Bridport. This latter shell is considered by Laube, and again by Brauns (Mittel-Jura. p. 177) as a synonym; but herein they labour perhaps under a mistake. Dr. Lycett (Ann. Mag. Nat. Hist. 1857, p. 176) cites *T. capitaneus* from the "Upper Lias Sands." Moore also cites it from the Upper Lias.

There are ten specimens in the Museum.

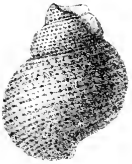
Locality—Dundry, Midford, &c. *Inf. Ool.*

AMBERLEYA, sp. Pl. 2, fig. 5.

Length 45 mm. (if complete.)

We have the cast of a shell which much resembles in form *Amberleya nodosa*, Lyc. and Morris. Part of the shell being left near the base of the last whorl, we notice that there were spiral ridges with oblique cross markings, as in *A. ornata*, Sow.

1^{a}



1^{b}

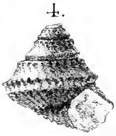
2^{b}

2^{c}

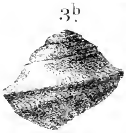
2^{a}

3^{a}

4.



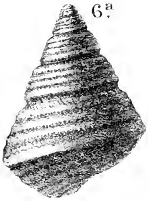
3^{b}



3^{c}

5.

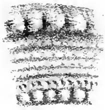
6^{a}



6^{c}

6^{b}

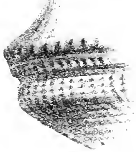
9^{c}



7.

7^{a}

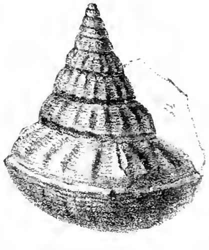
8^{b}



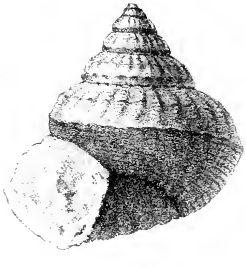
8^{a}

9^{b}.

10^{a}



10^{b}



9^{a}

G.H.Ford & C.L.Griesbach. Mintern Bros imp

This is in all probability *Eucyclus goniatus*, Desl. (Bull. Soc. Linn. de Norm. V. pl. 11, fig. 6) but we should not be justified in citing it as such till better specimens are found. It was described from the same horizon as our example.

Locality—Dundry. *Inf. Ool.*

AMBERLEYA, sp.

We have an incomplete shell 55 mm. long, and 40 mm. broad, which may probably be referred to *T. ornatus*, Goldf. (non Sow.) Petr. Germ. tab. 194, fig. 2.

The last whorl is almost devoid of shell, but shows on the cast the two chief strong keels, and above them two more; these are seen to be spiny where the shell remains. On the penultimate whorl are seen two strong keels, and two lesser spiny ridges above them, while below is a beaded line close to the suture.

It seems to differ from Sowerby's species, and the whorls are more convex or circular in outline.

The mouth and base of last whorl are unfortunately not preserved.

Locality—Dundry. *Inf. Ool.*

TURBO STODDARTI, n. sp. Pl. 2, fig. 1.

Length, if complete, 22 mm; breadth, 17 mm.

Shell turbinate; whorls convex, ornamented with numerous fine ridges, alternately stronger and fainter; the more pronounced set with round knobs or tubercles, the intermediate lines with much fainter longitudinally compressed dots, which however are sometimes absent; towards the base of the last whorl the intermediate lines vanish. There are very faint transverse growth-lines, slightly oblique in direction.

Our specimen does not show the mouth, but it is apparently not umbilicate. It differs from *T. cyclostoma*, Ziet. (Goldf. tab. 193, fig. 7) by the alternate arrangement of the markings; neither can it be identified with *T. Rutteri*, Moore, (Somerset N.

Hist. Soc. XIII., pl. 6, fig. 29, p. 210) if one may judge from descriptions.

This species is dedicated to Mr. Stoddart, F.G.S., well known to W. of England geologists.

We have only one specimen.

Locality—Dundry. *Inf. Ool.*

TURBO DUNDRIENSIS, n. sp. Pl. 2, fig. 2.

Shell elongate, acutely conical, not umbilicate. Whorls 7 angular, outline slightly convex above the keel, and then bending in towards a deep suture; angle sharp, only one quarter of the distance from the inferior suture. Aperture angular, trapezoidal. Above the keel are three bands or rows of tubercles, that nearest the suture is considerably the strongest; there are oblique transverse lines between these longitudinal ridges. On the base of the last whorl, *i.e.* below the keel, are nine ridges, the transverse lines seem to be continued between these, but they are well preserved only for a little distance below the keel in our specimen.

There are several shells which come near to this in shape, but which differ in the details of the ornamentation; we may refer to *T. imbricatus-suevicus*, Quenstedt, (Jura. tab. 24, figs. 11, 12) from the M. Lias; again, it differs from *Trochus concinnus*, Moore, (Som. N. H. Soc., XIII., pl. 4, figs. 28, 29) in being more acutely conical, as well as in the surface details. From *Trochus Gaudryanus*, D'Orbigny, (Pal. fr. Terr. Jur. 2 Gast., pl. 311, figs. 4—7) cited from the M. Lias, it is distinguished plainly by the character of the ornament near the suture.

This and allied forms might form a distinct genus; they seem to differ from the recent Turbo.

There are three specimens in the Musem.

Locality—Dundry. *Inf. Ool.*

TURBO SHALERI, n. sp. Pl. 2, fig. 3.

Height, 12 mm. Greatest breadth, 20 mm.

Shell depressed, wider than long: spire little elevated: umbilicus open and deep. Whorls embracing, angular, two-keeled; the widest part of the whorls at the upper keel, so that the outline of the space between them is oblique to the axis of the shell.

The whole surface is ornamented with numerous rows of small tubercles, disposed in longitudinal and oblique transverse lines. These are of the same size on the keels as the rest of the surface.

Umbilicus surrounded with radiating short costæ or lengthened tubercles.

Dedicated to Professor Shaler, of Cambridge, U.S., whose companionship I have enjoyed along the Avon-section and in the Alps.

There are three specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

TROCHUS SANDERSII, n. sp. Pl. 2, fig. 4.

Height, if complete, 17 mm. Greatest breadth, 16 mm.

Shell conical, acute, widely umbilicate. Last whorl with two keels, the superior one projecting considerably beyond the other, so that there is the widest part of the shell: whorls with numerous transverse costæ oblique in direction and with longitudinal lines; where these cross are raised tubercles, so that the whole surface of the shell is scabrous. The costæ where they cross the keels form elevated sharp tubercles.

The umbilicus is surrounded with a row of elevated crests, from which costæ radiate over the base of the last whorl, and on the other hand are continued within the open umbilicus.

This shell has some resemblance to *Trochus bisertus*, Phill. (non *T. biserratus*, Goldf., pl. 178, fig 11) which wants however the second keel. The wide umbilicus distinguishes it from *T. bitorquatus*, H. and D. (Bull. Soc. Linn. Norm. V., p. 213.)

The apex of our single specimen is imperfect.

Locality—Dundry. *Inf. Ool.*

This is named after our President, Mr. W. Sanders, F.R.S.

TROCHUS DUPLICATUS, Sowerby.

1817 T. duplicatus, Sow. Min. Conch. pl. 181, fig. 5.
1844 Turbo duplicatus, Goldf. Tab. 179, fig. 2.
1850 Trochus............ D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 313, figs. 5—8.
1858 .... Qu. Jura, tab. 43, figs. 18—19, p. 314.
1867 .... Laube. Gast. von Balin, tab. 2, fig. 7.

Length 20 mm. Breath 15 mm.

Shell pyramidal, acute; whorls eight, concave; last whorl with a double tuberculate keel; base rather concave, rising rapidly towards the umbilicus. Mouth trapezoidal, differing in form from that of Goldfuss' figure, which I deem to be erroneous in this respect. There is an open umbilicus in some specimens.

Brauns (Mittel-Jura. p. 181) unites this species with *Turbo subduplicatus*, D'Orb., from the U. Lias. Laube also seems to take the same view. *T. Thouetensis*, H. and D. (Bull. Soc. Linn. de Norm. V. p. 212) is probably only a synonym also.

There are fourteen specimens in the Museum.

Localities—Dundry and Yeovil. *Inf Ool*

TROCHUS ZETES, D'Orbigny. Pl. 2, fig. 7.

1850 T. Zetes, D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 316, figs. 1—4, p. 281.
Syn? 1850 T. Mosœ, D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 320, figs. 5—8.

There can be little doubt about this identification.

Our specimens have a very smooth and glistening surface, and show markings similar to those of D'Orbigny's figures. That they are in the state of casts is shown by the shell remaining on part of the last whorl; it is thin however so that it does not hide the keels: in this condition it has more the appearance of *T. Mosæ*, D'Orb. from the Coralline Oolite of France (Meuse).

We have figured our specimen in this condition.

This latter may probably be only a synonym.

None of our specimens show whether there is an umbilicus, being more or less imbedded in the matrix.

There are five specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

TROCHUS NIORTENSIS, D'Orbigny.

1850 T. Niortensis, D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 315, figs. 5—8, p. 282.
1867 .... Laube. Gast. von Balin. pl. 2, figs. 6, p. 10.

There are in the Museum two specimens which agree precisely with D'Orbigny's description. The French locality given is from the Inferior Oolite (Bajocien) of Niort.

Locality—Dundry. *Inf. Ool.*

TROCHUS IBBETSONI, Morris and Lycett.

1854 T. Ibbetsoni, Lyc. and Morr. Gt. Ool. Moll. Univalves, pl. 10, fig. 4, p. 62.

We refer provisionally here certain specimens which agree in form with the description of the above species. But the texture and aspect of the shell is so like that of *Monodonta lævigata*, Sow.

that we suspect it may belong to this latter genus; the columella unfortunately is hidden in all our specimens.

The spine is conical, but the apex slightly blunted; the whorls five, slightly convex.

There are seven specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

TROCHUS WINWOODI, n. sp. Pl. 2. fig. 8.

Length 16 mm, (if complete). Greatest breadth, 13 mm.

Shell pyramidal, acute; whorls concave, with two prominent keels, one close to either suture. The whole surface of the shell is ornamented with fine elevated ridges, both longitudinal and obliquely transverse; these cross one another, and produce a minutely granulated appearance; where they cross the keels they are stronger, and form tubercles or costæ. The last whorl has two keels, separated by a deep narrow concave interspace, in which are tubercles as on the rest of the surface. The mouth is trapezoidal; umbilicus closed. The base is also similarly tuberculate.

There is some resemblance to Quensted's figure of *T. bijugatus* (Jura. tab. 65, fig. 9.)

This species is named after the Rev. H. H. Winwood, Hon. Sec. of the Bath Nat. Hist. and Arch. Field Club.

There is only one specimen in the Museum.

Locality (probably)—Dundry. *Inf. Ool.*

MONODONTA LÆVIGATA, Sowerby.

1818 Nerita lævigata, Sow. Min. Conch. pl. 217, fig. 1.
1854 Monodonta lævigata, Morris. Cat. Brit. Foss. p. 258.

This seems a somewhat variable shell as to elevation of the spire. It is always less elevated than Muenster's figure (Goldf. Petr. Germ. tab. 195, fig. 5) which is probably a different species.

The Museum possesses the original specimen figured by Sowerby.

There are twelve specimens here.

Locality—Dundry. *Inf. Ool.*

MONODONTA ACMON, D'Orbigny.

1847 Trochus Acmon, D'Orb. Prodr. I. p. 265.
1850 .... D'Orb. Pal. fr. Gast. pl. 314, figs. 1—4, p. 278.

There are in the Museum four shells, which are much more elevated than the last species, and which we place here, as they correspond, as far as we can judge, with D'Orbigny's description.

I fancy it probable that this may be a synonym of *M. Labadei*, D'Arch. (Lycett and Morris, pl. 11, fig. 2).

The French examples are cited from the Inf. Oolite of Bayeux.

Our four specimens are from Dundry.

Inf. Ool.

STRAPAROLLUS DUNDRIENSIS, n. sp. Pl. 2, fig. 9.

Height 9 mm. Breadth 18 mm.

Shell depressed, discoidal; excavate below, but the whorls forming one plane above. Last whorl convex, thick; its height being equal to half the total breadth of the shell, ornamented on the sides with spiral lines, which are finely tuberculate where they are crossed by the curved transverse ones. Upper angle of the whorl less than a right angle somewhat, its edge ornamented with numerous sharp tubercles, decussated by spiral lines. The upper surface of the whorl has four dotted spiral lines between the rows of tubercles. The umbilical region is imperfect.

There are two specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

STRAPAROLLUS, sp.

There is one specimen, 33 mm. in diameter, which is not perfect enough to be recognisable. In the almost equal depression of the surfaces, it is similar to *S. subæqualis*, D'Orb., but the tubercles and ornamentation seem to be similar to those of *S. tuberculosus*, Thorent. sp.

It is hoped that further specimens may be found.

CIRRUS NODOSUS, Sowerby.

1818 C. Nodosus, Sow., Min. Conch., pl. 219, figs. 1, 2, 4; and pl. 141, fig. 2.
Syn. 1818 C. Leachii, Sow., M. C., pl. 219, fig. 3
...... 1865 C. acutus, Cat. Foss. Museum Pr. Geol., p. 207, (non Sow.)

We have sufficient material in the Museum for proving the identity of these two species.

The original specimen of *C. Leachii*, figured by Sowerby, is deposited here, and we have some two dozen of the ordinary variety.

Only that one specimen shows the spines preserved, but several others show the bases from which they seem broken off short. It is a pity that the original figures were so sketchy.

The characteristic feature of the species as we would constitute it, is the possession in the upper whorls of a keel, near the suture, which evidently bore spines, the bases occasionally being well seen; the last whorl has two keels, the upper being the sharper and bearing the long spines, which are rarely preserved; on the base of the last whorl are four lesser and weaker ridges.

The whorls are crossed by transverse costæ, and it is where these pass over the keel that the spines occur; underneath and between the spines the surface is excavated in quadrangular depressions; in addition there are spiral lines over the surface of the whole shell. On the base of the last whorl are distinct transverse lines which cross the spiral lines.

The variable elevation of the spire is seen in Sowerby's figures. The spire is sinistral.

There are more than two dozen specimens in the Museum.

Localities—Dundry and Yeovil. *Inf. Ool.*

CIRRUS PYRAMIDALIS, n. sp. Pl. 2, fig. 10.

Shell acutely conical, whorls numerous, convex; a single slight keel or projecting ledge on the last whorl; the whorls are crossed by numerous rounded costæ which are prominent above the keel, but become almost obliterated below. The whole surface of the shell is adorned with a granulation formed by the crossing of spiral and transverse dotted lines (the cross lines are not seen in our figure). The umbilicus is surrounded by faint radiating costæ. The base of the last whorl is convex, and has decussating lines, but the costæ do not extend immediately below the narrow keel; they reappear however round the umbilicus.

We have not met with such variations in the height of the spire as are seen in the preceding species.

There are three specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA ELONGATA, Sowerby.

1819 Trochus elongatus, Sowerby. Min. Conch. pl. 193, figs. 2—3, (=Pleurotomaria, Index to ditto.)
1858 Pleurotomaria elongata, Quenstedt. Jura. tab. 52, fig. 3, and tab. 57, fig. 10.
Syn? 1819 Trochus abbreviatus, Sow. Min. Conch. pl. 193, fig. 5 (=Pleurotomaria, in Index.

Syn? 1831 Pleurotomaria conoidea, Desl. Coq. caract. pl. 4, fig. 4.

...... 1848 .... mutabilis, (var elongata and mutica) Desl. Mem. Soc. Linn. de Norm. VIII. pl. 10, figs. 14, 15.

...... 1850 .... conoidea, D'Orb. Pal. fr. Terr. Jur. 2 Gast. pl. 382, p. 472.

.... Ebrayeana, D'Orb. ibid. pl. 387, figs. 1, 2.

Length—one attains 70 mm. Breadth, 52 mm.

This is a variable shell; the bands on the adult whorls differ in appearance from those on the apical ones; the keel is not a simple elevated band, but is split up into several concentric lines in the young state; (this is less frequently seen in old shells.) Again, the keel is interrupted by cross ridges sometimes, as in D'Orbigny's figure (loc. cit. plate 382). There are decussating lines on the young whorls.

The band which marks the successive positions of the slit in the external lip (we may call it for short, "sinus-band") is very little elevated, and is crossed by curved lines.

If one may be allowed to judge from descriptions, I should account *P. Ebrayeana,* D'Orb. only this species in a different state of preservation.

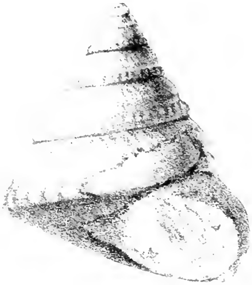
We have no form which corresponds exactly with *P. abbreviata,* Sow., but I fancy that it may be only a variety of this species.

There are nine specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA PUNCTATA, Sowerby, (non Goldfuss.)

1819 Trochus punctatus, Sowerby. Min. Conch. pl. 193, fig. 1 (and ? 4), (=Pleurotomaria, in Index.)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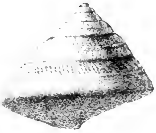
1b.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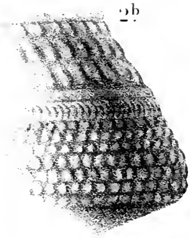
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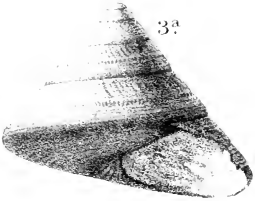
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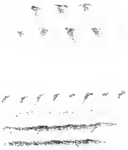
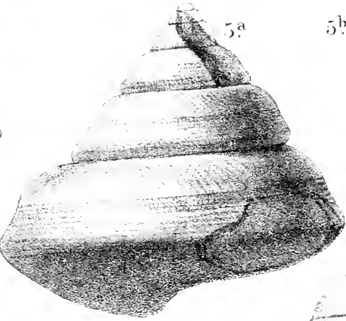

3b.


4a.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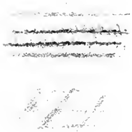
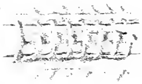
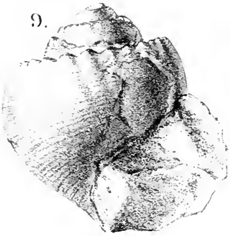

5b.


4b.


4c.


6.


9.


8.


7.

G.H. Ford & C.L. Griesbach.

Mintern Bros. imp

1850 Pleurotomaria punctata, D'Orb. Pal. fr. Terr. Jur. 2 Gast. pl. 399, figs. 11—13, p. 513.

1858 .... Quenstedt. Jura. tab. 57, fig. 8.

Length—one specimen attains 40 mm. Breadth 32 mm. Angle of spire 53°.

This seems the commonest species at Dundry. The shell is conical, the outline straight-sided; usually the whorls are not distinctly separated by a marked suture—indeed, the suture scarcely interrupts the outline; the encircling bands are not markedly salient; the sinus-band is the most prominent, it is elevated, with 2—3 concentric lines on it, crossed by curved lines; this is not seen in D'Orbigny's figure, his specimen being probably a poor one. If there is an umbilicus, it must be a very narrow one.

I fancy that *P. Allionta,* D'Orb., may be a synonym of this species; the absence of spiral lines round the umbilicus is probably not a constant character.

There are a dozen specimens in the Museum.

Localities—Dundry and Yeovil. *Inf. Ool.*

Professor Quenstedt regrets the number of species that have been described by D'Orbigny, saying that it is difficult to judge under which of these German specimens should be placed. I fancy if the specimens from Suabia were in as good a state of preservation as the French there would be no difficulty. Our Dundry specimens go to prove the validity of most of D'Orbigny's descriptions.

PLEUROTOMARIA SANDERSII, n. sp. Pl. 3, fig. 1.

Height, 38 mm. Greatest breadth, 32 mm. Angle of spire, 60°.

Shell conical, whorls 8—9, convex, somewhat ogival in outline from the sinus-band being in a concavity. The whole shell is adorned with knotted longitudinal lines, crossed by oblique transverse broad ridges and finer lines. The very prominent ridge, at the base of the last whorl, has the spiral lines stronger than on the rest of the shell, and is crossed by broad transverse costæ. There is apparently no umbilicus: Base very slightly convex, with concentric lines, which seem to cease about half-way towards the umbilicus.

The sinus-band is concave, and is crossed by curved lines with one medium longitudinal line.

This form is very near to *P. mutabilis* var *cœlata*, Desl. (Mem. Soc. Linn. de Norm. VIII. pl. 10, fig. 17). I do not even adopt the varietal name, for ours differs in the whorls being more convex in outline, and the description of the sinus-band is quite different. Deslongchamps' species has been dismembered by D'Orbigny, and rightly I think.

We have only one specimen in our Museum.

Locality—Dundry. *Inf. Ool.*

It is named in honour of our President, Mr. W. Sanders, F.R.S.

PLEUROTOMARIA AGATHA, D'Orbigny.

1847 P. agatha, D'Orb. Prodrome I. p. 268.
1850 .... D'Orb. Pal. fr. Terr. Jur. 2 Gast. pl. 383, figs. 1—3, p. 474.
Syn? 1840 P. mutabilis var cœlata, Desl. Mem. Soc. Linn. de Norm. VIII. pl. 10, figs. 17.

Height 19 mm. Breadth 22 mm. Angle of spire, 65°.

There is doubt about this identification. I do not feel quite sure that this and *P. mutabilis* as restricted by D'Orbigny are distinct species. D'Orbigny has apparently merely copied on his Plate (384) the drawing of Deslongchamps' var. *corrugata*.

We have two specimens; one agrees with the description given by D'Orbigny, except that the angle is a little wider; the other is narrowly umbilicate, but the other characters induce me to place it here; its angle too is equally wide, and the outline of the shell is a little concave, so that one specimen approaches to *P. circumscalata*, D'Orb., though it has not the groove on the base of the last whorl; the other to *P. mutabilis*, D'Orb., though it again has not the smooth space on the base. The sinus-band in this latter specimen agrees perfectly with that of the species under which we have placed it; in both specimens, the base of the last whorl is flat.

There are two specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA BESSINA, D'Orbigny.

1860 P. Bessina, D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 376, p. 460.

Syn? 1848 P. mutabilis var patula, Desl. Mem. Soc. Linn. de Norm. VIII. pl. 10, fig. 12.

Height 29 mm. Greatest breadth, 35 mm.

This seems a good species. Ours agree precisely with D'Orbigny's description; it is remarkable that minute characters should be constant over so large an area, unless they were of specific value.

It has been already cited by Dr. Wright from Dundry, (Q. J. G. S. XVI. p. 36).

There are two specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA AMYNTAS, D'Orbigny.

1850 P. Amyntas, D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 392, figs. 6—10, p. 495.

Height 40 mm. Greatest breadth, 33 mm. Angle of spire, about 58°.

Most of our specimens agree so well with the descriptions of the type, that we have little hesitation in placing them here. One a little larger (50 mm. in height) has the last whorl slightly concave between the suture and the sinus-band, but the apical whorls of the same are like the other specimens.

There are eight specimens.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA ALLICA, D'Orbigny.

1847 P. Allica, D'Orbigny, Prodrome I., p. 268.
1850 .... D'Orbigny, Pal. fr. Terr. Jur. 2, Gast. pl. 390, p. 490.

Height, 40 mm. Greatest height, 32 mm. Angle of spire about 54°

Shell conical, not umbilicate; whorls slightly convex, with a rounded angle close to the suture, so that a ledge is formed, where one whorl joins the other. The whole surface of the shell is minutely cancellate from the decussation of spiral raised lines and oblique transverse ones; the latter slope in different directions on the two sides of the sinus-band. Sinus-band in middle of the whorl, broad, elevated, crossed by curved lines, and with two spiral finely dotted lines. Base of last whorl slightly convex, surface cancellated like the rest of the shell.

This shell agrees in form with the French one; if the ornamentation seems to differ it is probably merely that ours is better preserved.

Our difficulties in deciding what is a species would be much less if all specimens were found in an equally good state with the present one.

There is only one specimen in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA SULCATA, Sowerby.

1819 Trochus sulcatus, Sowerby, Min. Conch., pl. 220,
fig. 3 (Pleurotomaria in Index)
non Deslongchamps.

Height 24 mm. Greatest breadth, 30 mm

The original specimen of the Min. Conch. is in our Museum.

We quite agree with D'Orbigny that *P. sulcata*, Desl., is a distinct species (= *P. unisulcata*, D'Orb.)

Sowerby's figures are sufficient to distinguish it from other Dundry forms.

The whorls are convex but not angular; the younger ones have fine transverse costæ, and the older ones faint transverse lines curved in opposite directions above and below the sinus-band; there are faint longitudinal lines, specially below the suture, Sinus-band not in the middle, but about one-third from the lower suture, and generally forming a concave depression; it is crossed by curved lines. Umbilicus pretty wide. The outline of the shell is too curved and convex to allow of a definite angle being taken.

There are eight specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

Professor Quenstedt (Jura., p. 404) suggests that *P. Ajax*, D'Orb., may perhaps belong here. I cannot agree with him. It may be wearisome, as he says, to have to determine imperfect specimens; but the attention which D'Orbigny paid to this genus has resulted, I think, in proving the fact, that it was one extraordinarily prolific in species, and that the differential characters were constant over a considerable area. It is much to be regretted that the Suabian specimens are not more perfectly preserved, for we might then have had proofs of forms intermediate between, and linking together, some of D'Orbigny's species; but imperfect specimens can scarcely invalidate the determinations of the latter.

PLEUROTOMARIA SUBDECORATA, Muenster, (? non D'Orb.)

1844 P. subdecorata, Mü. Goldf. Pet. Germ., tab. 185, fig. 3.

Height, 37 mm. Breadth, 38 mm. Angle of spire, 80°

Referred with great doubt to Muenster's species, of which it has a similar form and markings, but the umbilicus is wide and deep, so that it differs entirely from D'Orbigny's description.

The cancellated character of the ornamentation is best preserved on the young whorls, which are obtusely subangular; the older whorls are convex and less angular. The sinus-band is slightly below the middle of the whorl; it is convex, with 3—4 raised longitudinal lines, crossed by the usual curved lines. The base is convex, sloping steeply into the deep umbilicus.

Oppel (Juraf. p. 259) cites the species from the Upper Lias, and considers D'Orbigny's shell the same species. It is for those who have access to the German type to decide.

There is only one specimen in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA MONTICULUS, Deslongchamps.

1848 P. Monticulus, Desl. Mem. Soc. Linn. de Norm. VIII. pl. 13, fig. 5, p. 143.
1850 .... D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 388, figs. 6—10, p. 485.

Height 25 mm. Breadth 25 mm.

Our specimen agrees fairly with the French description.

The outline of the spire is an obtuse cone bounded by curved lines; whorls convex, with oblique costæ on the upper part of whorl, crossed by longitudinal lines; the umbilicus is deep; the base is imperfect, but there is evidence of radiating ridges; the sinus-band is concave, and crossed by curved lines only.

There is one specimen in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA OBCONICA, n. sp. Pl. 3, fig. 6.

Height 29 mm. Greatest breadth, 30 mm.

Shell conical; apex obtuse; the newer whorls not increasing at the same rate as the apical ones: the outline is curved, and the cone of blunted form.

Whorls seven, obtusely angular; the part above the sinus-band becomes almost concave in the old whorls; the part below is inclined to be squarely-rounded; the surface is marked with oblique transverse lines above, and transverse lines as well as longitudinal lines below—the latter being the stronger; on the apical whorls the transverse lines are so strong that they constitute costæ.

The umbilicus is open; the base of last whorl is very slightly conical; lines radiate from the umbilicus outward. Sinus-band elevated.

I first was disposed to consider this a less depressed form of *P. sulcata*, as the ornamentation is precisely the same, but the sinus-band is in a depression in that species, and here it is elevated; moreover, we have no transition between the two forms; one is a more obtuse cone, and the difference seems constant.

There are two specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA DISTINGUENDA, n. sp. Pl. 3, fig. 2.

Height 18 mm. Breadth 19 mm. Angle of spire 70°.

Shell conical, regular; whorls straight-sided, ornamented with rows of separate tubercles, placed obliquely in opposite directions on either side of the sinus-band. Above the band are three rows of compressed tubercles; below it are three of smaller round tubercles, and then three to four of larger ones (the distinction is not well seen in our plate) which form the angle in the last whorl; sinus-band with a central salient ridge, and crossed by curved lines; base of last whorl slightly convex. The umbilicus was probably closed, but our specimen is imperfect here.

This differs from *P. punctata* by having rows of detached tubercles instead of continuous tubercular lines, by the greater angle of the spire, and convexity of base of last whorl.

There is one specimen in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA DUNDRIENSIS, n. sp. Pl. 3, fig. 3.

Height (if complete) 27 mm. Breadth 30 mm. Angle of spire 75°.

Shell depressed, conical; apex, acute; whorls about seven, flat, the older ones slightly rounded into the suture, while the upper part of the shell is a straight-sided cone. The whole surface is ornamented with strong spiral lines, these are crossed by transverse ones fainter below the sinus-band, but above it they are so strong that they appear as ridges, being also more oblique in direction.

There is a narrow umbilicus; sinus-band sub-median, slightly salient, with the central line crossed by curved lines.

The base of the last whorl is somewhat concave midway to the umbilicus, around which are radiating and concentric lines.

The species to which this comes nearest may be said perhaps to be *P. Mysis*, D'Orb.

There are two specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA SUBRETICULATA, D'Orbigny. Pl. 3, fig. 7.

1849 P. subreticulata, D'Orb. Prod. 1, p. 260.
1850 .... D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 392, figs. 1—5, p. 494.

Height 30 mm. Breadth 27 mm. Angle of spire about 65°.

It is not quite clear whether there is an open umbilicus or not in our specimens, but there seems to be a narrow one. In all other respects they agree with the description in the Pal. française, so that we have little doubt about their identification. The columella is straight, making the mouth very angular.

The surface is much more granulated than in *P. Amyntas*, D'Orb.

There are three specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

Our figure does not show the reticulation of the surface.

PLEUROTOMARIA GRANULATA, Sowerby.

1819 Trochus granulatus, Sow., Min. Conch., pl. 220, fig. 2. Pleurotomaria in Index to ditto (non Goldf. nec D'Orb., nec Qu., nec Lycett.)

1848 P. granulata var reticulata, Desl., Mem. Soc. Linn. Norm. VIII. pl. 16, fig. 6.

Height, 22 mm. Greatest breadth, 26 mm.

We ought to have the original specimens drawn by Sowerby, as they belonged to the Miller collection; they have, however, apparently been lost; still we have some in a good state of preservation, and agreeing with his figure.

The shell is conical, depressed; whorls convex, slightly scalate; base of last whorl very convex; here the concentric lines are so much stronger than the radiating lines, that the granulated appearance is there feeble; there is a tendency for them to disappear half-way to the umbilicus: sinus-band, with a convex ridge of several lines, crossed by strong curved lines.

We approve of D'Orbigny's separating this from the next species; but we are not sure that his is the same as Sowerby's species; we take his pl. 380, figs. 1—6, to be only a variety of his *P. Palæmon*, and which might therefore be termed var. ***Orbignyana.***

Deslongchamps' fig. 6 is very truthful. Our shell has a much more elevated spire than Goldfuss' figure, but the clathrated ornamentation is very similar; it is, however, in ours coarser and much more pronounced, and the sinus-band is nearer the middle of the whorl.

I differ entirely from Dr. Braun's views, as to the constitution of this species.

There are five specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA PALÆMON, D'Orbigny.

1847 P. Palæmon, D'Orb., Prodrome I., p. 267.
1850 .... D'Orb., Pal. fr. Terr. Jur. 2 Gast., pl. 380, figs. 1—11.
Syn. 1848 P. granulata var plicopunctata and lævigata, Desl. Mem. Soc. Linn. Norm. VIII., pl. 16, figs. 5 and 7.

Height, 25 mm. Greatest breadth, 43 mm.

It seems probable from an examination of Dundry specimens, that D'Orbigny is wrong in attributing the specimens of his pl. 380, figs. 1—6, to Sowerby's species: they differ therefrom by the more depressed form and character of ornament; they are distinguished by the strong radiating and transverse ridges on the whorls, and the absence or faintness of the longitudinal lines, so that the granulated character is absent. The sinus-band is different, being a simple convex ridge crossed by faint curved lines; it is also further from the middle of the whorl. The upper figures of D'Orbigny's pl. 380 are probably the same species as the lower; they seem to differ only by the base of the last whorl being still more convex, and the radial lines thereon being stronger; the form seems almost as much depressed.

There are in the Museum nine specimens of various sizes.

Localities—Dundry and Yeovil. *Inf. Ool.*

PLEUROTOMARIA PALLIUM, Morris.

1843 P. Pallium, Morris, Catalogue Brit. Fossils, p. 158.
Syn. 1819 P. (Trochus) ornata, Sow., Min. Conch., pl. 221, fig. 1 (non Defrance, nec Deslong., nec D'Orbigny.)

Height, 35 mm. Greatest breadth, 46 mm.

This seems a good species: it differs considerably from any of the species described by Deslongchamps, and would seem to be confined to England. Sowerby's figure is rough but characteristic.

The broad rounded costæ incline in opposite directions towards the sinus-band, which interrupts them. The form is that of a depressed regular cone, the whorls being separated by a deep suture. The umbilicus seems open. The base of the last whorl is convex; it is marked by concentric and undulating radial lines. The sinus-band has a medium convex ridge crossed by curved lines.

I believe Dr. Brauns (Mittel-Jura, p. 189) to be wrong in uniting this with *P. granulata*, Sow.

There are three specimens in the Museum.

Localities—Dundry and Yeovil. *Inf. Ool.*

PLEUROTOMARIA ACTINOMPHALA, Deslongchamps.

1848 P. actinomphala, Desl. Mem. Soc. Lin. de Norm. VIII. pl. 18, fig. 1, p. 38.
1850 .... D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 374, p. 458.

Height 30 mm. Greatest breadth 50 mm.

We place here our specimens with strong ridges radiating from the wide umbilicus. Some agree very well with the figures in the Pal. française, others come nearer to Deslongchamps' original delineation. It seems to be a variable species, tending sometimes towards *P. ornata*, Defr.

There are six specimens in the Museum.

Localities—Dundry and Yeovil. *Inf. Ool.*

It has been cited by Dr. Wright, (loc. cit. p. 35.)

PLEUROTOMARIA ACTÆA, D'Orbigny.

1847 P. Actæa, D'Orb. Prodrome 1, p. 207.
1850 .... D'Orb. Pal. fr. Terr. Jur. 2, Gast, pl. 375, p. 409.

Height 48 mm. Breadth 84 mm.

We believe this to be a good species. The umbilicus is wide and steep. The whorls are convex; the general form somewhat scalate.

It was cited by D'Orbigny from Dundry, though it does not appear in Morris's catalogue.

There are three specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA ARMATA, Muenster.

1848 P. armata, Muenster, in Goldfuss. Petr. Germ. tab. 186, fig. 7.
1850 .... D'Orbigny. Pal. fr. Terr. Jur. 2, Gast. pl. 368.

Height 53 mm. Breadth 68 mm.

There are several imperfect and two good specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA STODDARTI, n. sp. Plate 3, fig. 5.

Height 70 mm. Angle of spire, 67° to 75°.

Shell conical, acute; whorls flat in the middle, convex above and below where they bend into the deep suture, which separates them profoundly. The ornamentation consists of longitudinal lines, and oblique decussating transverse lines, inclined as usual in opposite directions on either side of the sinus-band; the young whorls have a cancellated appearance, but in the old whorls the part of the whorl above the sinus-band has a smooth appearance from the absence of the longitudinal, and faintness of the cross-lines. Sinus-band broad, with three spiral bands crossed by curved lines; it is below the middle of the whorl, and is not salient. The umbilicus is broad and deep. Base of last whorl convex.

It differs from *P. subplatyspira* and *physospira*, D'Orb., by the deep divisions between the whorls, the more open angle, and the bandlets of the sinus-band.

The specimen figured is about half the height of our larger one.

There are two specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA SAUZEANA, D'Orbigny.

1847 P. Sauzeana, D'Orb. Prodrome I. p. 267.
1850 .... D'Orb. Pal. fr. Terr. Jur. 2, Gast. pl. 373.

Height (if complete) 95 mm.

Our shell differs only from the type in having a little wider angle, but the form of the whorls and position of the tubercles, &c. are similar.

There is one specimen in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA FASCIATA, Sowerby.

1816 Trochus fasciatus, Min. Conch. pl. 220, fig. 1, (non Deslong.) Pl. in Index to ditto.

Height, 60 mm. Angle of spire, 65°

Our specimens correspond exactly with Sowerby's description; his figure, though sketchy, is faithful as to form. The surface of this shell is covered with decussating lines; the transverse ones are inclined in opposite directions on either side of the sinus-band; this is almost median, rather above the middle than below it, and contains longitudinal crossed by curved lines. The outline of the whorls is subangularly convex. The ornamentation is more marked below the sinus-band than above it.

It is distinguished from Deslongchamps' var *physospira* by the absence of tubercles on the young whorls, less scalate outline, &c. D'Orbigny seems quite right in making separate species of what the former author considered erroneously to be Sowerby's shell in question.

The nearest to it in form is *P. transilis*, D'Orb., but that has no umbilicus.

Dr. Brauns may perhaps be right (Mittel-Jura., p. 190) in considering *P. Niortensis*, D'Orb., as a synonym of this species, but the position of the sinus-band seems to be different.

There are three specimens in the Museum.

Locality—Dundry. *Inf. Ool.*

PLEUROTOMARIA PROTEUS, Deslongchamps.

1848 P. Proteus, Deslong., Minn. Soc. Linn. de Norm. VIII., pl. 1, fig 1, and pl. 2, fig. 1.

We have an internal cast of a large shell which may probably be referred here; the size and shape are the only characters left to judge by, as we have no specimen with the shell on. Its height is six inches.

It has been cited before by Dr. Wright and Mr. Etheridge.

One specimen only.

Locality—near Bath. *Inf. Ool.*

PLEUROTOMARIA YEOVILENSIS, n. sp. Pl. 3, fig. 4.

Height, 14 mm. Greatest breadth, 21 mm.

Shell depressed, widely umbilicate. Whorls about 6, angular and prominent at the band, concave above and below this; ornamented with numerous costæ (about 40), which are prominent on the edge of the last whorl, but are interrupted by the salient sinus-band. The base of the last whorl has numerous costæ radiating from the open umbilicus, these are crossed by spiral lines, giving a somewhat cancellated appearance. These spiral lines are continuous over the whole shell, and the cancellation in the younger whorls is beautifully marked. The base of the last whorl has also a concave depression just below the angle of the whorl, from this again it rises somewhat convexly towards the umbilicus.

The sinus-band is very salient; it bears a medium longitudinal line, and a pair of side ones, all crossed by curved transverse lines.

The specimen figured is in the collection of Mr. Stoddart, F.G.S. There is a badly preserved one in the Museum.

Locality—Yeovil and Dundry. *Inf: Ool.*

PLEUROTOMARIA TEXTILIS, Deslongchamps.

1848 P. textilis, Desl. Mem. Soc. Linn. de Norm. VIII. pl. 9, fig. 2, pl. 63.
1850 .... D'Orb. Pal. fr. Terr. Jur. 2. Gast. pl. 391, fig. 6, 10, p. 492.
Syn? 1854 .... Gaudryana, D'Orb, Pal. fr. Terr. Jur. 2, Gast. pl. 364, fig. 11, 12, p. 447.

This species is represented by one specimen.

Locality—Dundry. *Inf. Ool.*

TROCHOTOMA GRADUS, Deslongchamps.

1842 T. gradus, Desl. Mem. Soc. Linn. de Norm. VII. pl. 8, f. 4, 7.
Syn. 1842 Ditremaria bicarinata, D'Orb, Pal. fr. Terr. Crétacés 2, p. 277.

......	1850	....	D'Orb, Pal. fr. Terr. Jur. Gast 2, pl. 340, f. 8, 11.
Syn ?	1829	Solarium calyx, Phill.	Geol. York, I. pl. 11, f. 30.
......	1850	T. carinata, Lycett.	Ann. Mag. Nat. Hist. VI. p. 417 (no fig.)
......	1857	....	Lycett. "Cotteswold Hills Handbook, pl. 4, fig. 5.

There is no doubt that our shell is the same as *T. bicarinata* of D'Orbigny. Not having seen Phillips' shell I am unable to say whether it is a separate species. D'Orbigny considered it different.

There are five specimens. in the Museum

Locality—Dundry. *Inf. Ool.*

TABULAR LIST OF SPECIES.

1 Purpurina Bellona, D'Orb.
2 .... inflata, n. sp. Pl. 3, fig 9.
3 Euspira Bajocensis, D'Orb. Pl. 1, fig 2 and 4.
4 .... Zelima, D'Orb. (?) Pl. 1, fig 1.
5 .... Dundriensis, n. sp. Pl. 1, fig 3.
6 .... canaliculata, Lyc.
7 Chemnitzia lineata, Sow.
8 ....procera, Desl.
9 ....Heddingtonensis, Sow.
10 Nerinea bacillus, D'Orb.
11 .... funiculus, Desl.
12 Melania undulata, Desl.
13 Alaria myurus, Desl.
14 ...... Dundriensis, n. sp. Pl. 1, fig 5.
15 ...... trinitatis, n. sp. Pl. 1, fig 6.
16 ...... Perrieri, Piette.
17 ...... Lorieri, D'Orb.
18 ...... Etheridgii, n. sp. Pl. 1, fig 7.
...... sp.
19 ...... Lotharingica, Schlumb.
20 Littorina ædilis, Muen.
21 .... biarmata, Muen.
22 .... recte-planata, n. sp. Pl. 2, fig 6.

23 Neritopsis Bajocensis, D'Orb.
24 Phasianella striata, Sow.
25 Amberleya princeps, Roem.
26 .... ornata, Sow. Pl. 1, fig 9.
27 .... goniata, Desl. (?) Pl. 2, fig 5.
.... sp.
28 Turbo Stoddarti, n. sp. Pl. 2, fig 1.
29 ... .. Dundriensis, n. sp. Pl. 2, fig 2.
30 ...... Shaleri, n. sp. Pl. 2, fig 3.
31 Trochus Sandersii, n. sp. Pl. 2, fig 4.
32 ... . Zetes, D'Orb. Pl. 2, fig 7.
33 Trochus Ibbetsoni, M. and L.
34 ... . Winwoodii, n. sp. Pl. 2, fig 8.
35 Monodonta lævigata, Sow.
36 .... Acmon, D'Orb.
37 Straparollus Dundriensis, n. sp. Pl. 2, fig 9.
.... sp.
38 Cirrus nodosus, Sow.
39 ...... pyramidalis, n. sp. Pl. 2, fig 10.
40 Pleurotomaria elongata, Sow.
41 .... punctata, Sow.
42 .... Sandersii, n. sp. Pl. 3, fig 1.
43 .... Agatha, D'Orb.
44 .... Bessina, D'Orb.
45 .... Amyntas, D'Orb.
46 .... Allica, D'Orb.
47 .... sulcata, Sow.
48 .... subdecorata, Muen. (?)
49 .... Monticulus, Desl.
50 .... obconica, n. sp. Pl. 3, fig 6.
51 .... distinguenda, n. sp. Pl. 3, fig 2.
52 .... Dundriensis, n. sp. Pl. 3, fig 3.
53 .... subreticulata, D'Orb. Pl. 3, fig 7.
54 .... granulata, Sow.
55 .... Palæmon, D'Orb.

56 .... pallium, Morris.
57 .... actinomphala, D'Orb.
58 .... Actœa, D'Orb.
59 .... armata, Muen.
60 .... Stoddarti, n. sp. Pl. 3, fig 5.
61 .... Sauzeana, D'Orb.
62 .... fasciata, Sow.
63 .... proteus, Desl.
64 .... Yeovilensis, n. sp. Pl. 3, fig 4.
65 .... textilis, Desl.
66 Trochotoma gradus, Desl.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1, a, b.	Euspira Zelima, D'Orb.	Natural size.
... 2, a, b.	.... Bajocensis, D'Orb.	......
... 3,	.... Dundriensis, n. sp.	......
... 4, a, b.	.... Bajocensis, variety.	......
... 5, a.	Alaria Dundriensis, n. sp.	......
... 5, b.	....	portion of surface enlarged.
... 6,	.... trinitatis, n. sp.	Natural size.
... 7,	.... Etheridgii, n. sp.	......
... 8,	.... sp.	......
... 9,	Amberleya ornata, Sow.	

PLATE II.

Fig. 1, a,	Turbo Stoddarti, n. sp.	Natural size.
... ... b,	....	portion of surface enlarged.
... 2, a,	...... Dundriensis, n. sp.	Enlarged,
... ... b,	....	aperture enlarged, outer margin imperfect.
... ... c,	...... line indicating the natural size of (a).	
... 3, a,	...... Shaleri, n. sp.	Natural size.
... ... b,	.... another specimen	...
... ... c,	.. .. portion of surface of (a),	enlarged.
... 4,	Trochus Sandersii, n. sp.	Natural size.
... 5,	Amberleya goniata, Desl. (?)	......
... 6, a,	Littorina recteplanata, n. sp.,	slightly enlarged.
... ... b,	....	portion of surface enlarged.

Fig. 6, c,	.... line indicating natural size of (a)
... 7,	Trochus Zetes, D'Orb., slightly enlarged.
... ... a,	... . line indicating the natural size.
... 8, a,	.... Winwoodii, n. sp. Natural size.
... ... b,	.... portion of surface enlarged.
... 9, a,	Straparollus Dundriensis, n. sp. Side view, natural size.
... ... b,	.... superior view.
... ... c.	.... portion of surface magnified.
...10 a,	Cirrus pyramidalis, n. sp. Natural size.
... ... b,	.... another specimen. ...

PLATE III.

Fig. 1, a,	Pleurotomaria Sandersii, n. sp. Natural size.
... ... b,	.... portion of surface enlarged, showing the band.
... 2, a,	.... distinguenda, n. sp. Natural size.
... ... b,	.... portion enlarged.
... 3, a,	.... Dundriensis, n. sp. Natural size.
... ... b.	.... portion with band enlarged.
... 4, a,	.... Yeovilensis, n. sp. Natural size.
... ... b,	.... portion slightly enlarged.
... ... c.	.... band, further enlarged.
... 5, a,	.... Stoddarti, n. sp, Natural size.
... ... b,	.... portion with band, enlarged.
... 6,	.... obconica, n. sp. Natural size.
... 7,	.... subreticulata, D'Orb. ......
... 8,	Purpurina Bellona, D'Orb. ......
... 9,	.... inflata, n. sp. ......

On the use of the Divining Rod in the neighbourhood of Bristol.

BY A. C. PASS, and E. TAWNEY.

Read March 12th, 1873.

BEING in a village on the Mendips a short while ago, at a place where they were sinking for iron, we found that the Divining Rod, or Dowsing Fork was still in actual use there for the discovery of courses or deposits of mineral ores and springs of water.

Having expressed our astonishment to an intelligent mining foreman, the latter admitted that he had not seen the method used in his native district (S. Wales), but said, that since he had been in the Mendips he had become a convert to its use; he believed that those who practised this divination could really point out the places of fissures, or veins, or deposits, where metal ores were more or less disseminated.

We then suggested that the country-rock, (New Red Conglomerate and Carboniferous Limestone) was so full of joints, fissures, and even caverns, which all contain usually small masses of iron ore and sometimes lead, that it would be almost hard to find a place absolutely free from them; also that the larger fissures or veins showed often an indication on the surface, either a depression, or a watery ground, or a redder soil, so that one might do just as well without a rod.

He replied to this, that it was not only infallible in the field and in the mine, but that they could detect by it metal wherever placed; that money might be detected when hidden. On our asking whether the diviners here could detect a coin concealed under one of a series of objects, he testified that they certainly could if they cared to.

This seemed to us a good opportunity of testing their powers by an experiment. We therefore asked our friend, the foreman, to send to the practitioner of this ancient art, and use his influence with him to induce him to submit to the trial.

We were successful in attaining the attendance of the two reputed best operators, and both expressed themselves willing and able to find the money which we were to conceal.

We took the older and better hand first.

A shilling was to be placed under a series of objects, such as hats and handkerchiefs placed on the floor,—he stipulated that the money should be in copper pence,—and he guaranteed to find it if there were no disturbing causes.

The last clause gave room for evasion and vitiation of the experiment, so we asked what such could be? He answered, metal in the hats, or a spring of water, or minerals under the house. We showed him that there was no metal about the hats, and then asked him to try over the room before we laid the hats in order to see whether there were any of these things he feared beneath. He tried, and said there was water passed over in going across the room (E. & W.) We begged him to try up and down the room, (N. & S.,) he found no indications here, nothing caused the rod to turn over, and he admitted that it was a suitable place.

We may mention that he professed to know water from metallic ores by a tingling in the fingers.

When he had retired from the room, we laid the following articles in a linear series, using handkerchiefs as we had not enough hats, these were in order.—(1) hat—(2) coloured handkerchief—(3) pair of thick gloves—(4) hat—(5) white handkerchief—(6) hat—(7) hat.

The coins were placed under No. 5.

On retiring he objected to hat No. 1 as being too near the wall; we appeared loth to move it, and begged him to let it remain. He evidently made a note of this.

Beginning at No. 7, the rod did not turn over. He was very deliberate in his proceedings, and had an absorbed manner, with an assumption, if one might so say, of a professional demeanour. At No. 6 no indications were shown. On reaching No. 5 the rod turned over; this was the only *white* handkerchief of the series. At No. 4 there was a slight indication, the rod did not turn over completely: this small sign seemed to be connected with doubt in his mind, he tried again two or three times before going to the next object. At No. 3 there was no indication at all, although there were heavy metal buttons on the gloves. At No. 2 a half indication, he tried here several times as if he could not make up his mind. He reached now No. 1, the hat we seemed to wish to keep; the rod turned over at once, he said this was the strongest indication for it turned over each time he tried. He would not decide at once however, but went over the whole series again, as slowly as before, and with the same results. The metal buttons of No. 3 were quite unperceived, while the hat No. 7, and the white handkerchief seemed to fix his attention. Saying that he was puzzled, he went over the whole series a third time, but a little more expeditiously. Finally, he said that No. 7 gave the strongest indication, and the white handkerchief next, but of the two he took up the latter and found that he was right.

This seemed to us very unsatisfactory, there being two almost equally strongly indicated, but the weaker of the two being chosen. He refused to repeat the experiment even for a sovereign. He had evidently been much puzzled, but having made a lucky hit, no doubt thought it best to retire with his shilling and the modicum of fame he had earned.

As the white handkerchief was the most conspicuous object, he was only likely to pitch on that as probably covering the coveted coin: then the curved brims of two of the hats almost enabled one to see that the coin was not there, so that the objects to choose between were really reduced to very few.

The fact of the metal buttons having no action on the rod simply because he did not suspect them, shows that, to say the least, there is no physical foundation for the supposed action of metals on the rod through the human being, and as physical laws are immutable, the notion must be a mere superstition.

The neighbourhood of Bristol seems to be distinguished by its lingering here longer than in other places.

We next tried the other diviner, since he expressed himself willing to show us his powers. He was considerably younger than the other, and according to our notions, compared to the more practised hand, he was more or less of a bungler; he was however all the more confident.

Our friend, the foreman, who was a believer, as we have said, suggested that we should lay the hats on a row of chairs this time. We did so, the order of the concealing objects being the following:—(1) hat—(2) pair of gloves—(3) coloured handkerchief—(4) white handkerchief, carefully laid in a heap—(5) hat—(6) white handkerchief—(7) coloured handkerchief—(8) hat.

The dowser was then called in and commenced his survey: he had evidently heard that white handkerchiefs were the thing, for he showed partiality to them at once.

At No. 1, a hat, there was no sign. No. 2, gloves, no sign. No. 3, a coloured handkerchief, a small indication, the rod did not turn over quite, though he tried several times. No. 4, a white handkerchief, the rod turned over persistently. No. 5, a hat, no sign. No. 6, another white handkerchief, half an indication. No. 7, a coloured handkerchief, the rod turned over. No. 8, a hat, no sign.

He went over the whole series a second time, and finally was caught with the bait of the efflated white handkerchief, No. 4. There was nothing under. The coins were under No. 6.

Being nothing daunted, but only vexed at missing the shining coin, he consented to a new trial:

We may notice by the way that his hands were not kept by any means still when the rod turned over, there was plainly an appearance of its being a voluntary act.

In the next trial the series was as follows, (1) hat—(2) hat—(3) white handkerchief—(4) coloured handkerchief—(5) hat—(6) white handkerchief—(7) coloured handkerchief—(8) hat.

On trying this time he still showed a partiality for handkerchiefs, (we had always so far hidden the coin under such) but now he varied the colour in his preferences: so had we in fact, the coin was concealed under No. 7.

The movements of the rod were these—1, a hat, no sign. 2, a hat, no sign again. 3, a white handkerchief, slight sign, but not a complete turning over of the rod, and he passed on satisfied it was not here. 4, a coloured handkerchief strong sign, the rod turned over repeatedly. 5, a hat, no sign. 6, a white handkerchief, slight sign. 7, a coloured handkerchief, very feeble sign. 8, a hat, no sign.

He next tried back over the whole series, and with the same results: he seemed to settle on No. 4. The foreman suggested that this chair with its burden should be moved to another part of the room. It was moved accordingly, and the dowser tried it in the new position; there were the same signs, and he confidently chose this one. He lifted up the handkerchief but there was nothing under it. Curiously enough we had chosen a coloured handkerchief, but it was No. 7 where we had placed the coin.

We considered these two failures quite enough. From observation of his way of proceeding and movement of the fingers, we became convinced that the turning up of the rod was by no means an involuntary or unconscious act.

Being considerably disconcerted, our practitioner tried to escape the effect of his failures by trying the chair alone. Of course he obtained the turning over as he wished it; he then maintained that there were nails in the chair. We all examined it but there was nothing of the sort.

Our friend, the foreman, now getting warmly interested, arranged a little experiment of his own while we were talking to the discomfited diviner. Going into the taproom (for we were in the village inn) he borrowed the hats of seven men and laid them on a bench in the passage or hall, putting some pence under one of them. The whole tap-room attended as audience. This time the poor diviner was utterly puzzled, and could not decide for a long period, though he went along the series over and over again. In the meanwhile as a fresh bystander dropped in they would lift up the hat to show how many pence there were, and this when the diviner's back was only half turned. No care was taken to replace the hat in the same position, they were too simple to think of such a thing The dowser might have found out at once the right hat by this means. Then again, when he came over where the money was, the rustics got excited and stared hard at the hat and the rod, so that he had only to glance at their faces to get the hints he wanted. This is a good illustration of the circumstances under which these men got their reputations.

After trying over and over again for about ten minutes, and getting indications at several wrong hats, at last he pitched on the right one, having obtained the clue he wanted. One of us had already left the place, considering him to have quite broken down again.

We have gone somewhat into detail, for it is only by observation of all the circumstances that these deceptions can be exposed; though we put our own interpretation on them.

There seems to us no mystery in the matter,—there is as much deception here as was ever practised by the medicine-man of savage tribes.

We maintain that the diviner showed a voluutary movement of the hands; we tried to imitate him; after a few trials we claim to have entirely succeeded. It seemed hopeless indeed at first, but there is a knack about it which after all is easily acquired when once the way is pointed out.

The tighter the forked twig is held the easier it turns—that is acknowledged on all hands. The method we use to start it is this:—The arms are held close to the sides, the twig being grasped in the proper manner as far as the fingers are concerned; then if the hands are slightly approached towards each other horizontally without the fingers being moved at all, it will be found enough to determine a starting of the rod, and if persisted in, the rod will turn over upwards towards the face of the operator. The least thing causes it to move, and when once it has fairly begun it cannot be stopped without relaxing the grasp. It will be understood from this how it will frequently turn over in the hands of novices without any conscious action of theirs, and therefore without their being necessarily able to do it a second time. We do not imagine however for a moment that it is usually involuntary with the professional dowsers; when a fee or its equivalent is to be had, we rather fancy, from our knowledge of human nature, that the rod is likely to act in the desired way.

Since our small experience of the Divining-rod we have been incited to look for other accounts of its use. It was only last November that one of her Majesty's Geological Surveyors expressed his surprise [Geol. Mag. 1872.] at its use in the Mendips.

We owe our thanks to Mr. Taylor, the very intelligent Librarian of the Bristol Library Society, for pointing our attention to the following account of the use of the dowsing-fork at Dundry in the year 1830.*

We quote most of it as it may be interesting to those who are living in sight of that hill. It relates to a trial for a spring of water.

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* Year Book of Recreation, 1830. Reprinted, W. Tegg, Cheapside, 1850, page 1590.

"Our friend, the farmer—holding the stick—traversed the court-yard in which the well had been dug with much gravity. So long as he kept aloof from the well there was no motion whatever in the stick: as we approached the water I thought I fancied a slight depression in the stem, but when held immediately over the well, the stem obviously declined, bent down, till it pointed to the ground, and the apparent attraction was so great that it turned quite round and was nearly broken from the fork. All this time the branches of the fork were firmly grasped, and the hands did not move in the smallest perceptible degree. Now let one take hold of a stick, as I have described, and he will find it impossible to move the stem without also moving his hands. Here there is a most singular mystery, for I cannot account for it on any supposition of peculiar muscular power or of sleight-of-hand.

We afterwards got him to exhibit many proofs of his art, one of which I will mention. We placed three hats on the ground, and under one of them (not allowing him of course to know which) we put a watch. He held the stick as before over each of them, and when he came to that which contained the watch, the sudden downward movement of the stem was amazingly palpable: it looked like magic.

I must now state a circumstance that tells against our faith in the Divining-Rod, it is, that the stick was wholly inert and passive when used by us, although we rigidly followed the instructions of the professor. This objection was got rid of by the assertion that there are few in whose hands the stick has any power. But this savours so much of mockery, that did not the man's character forbid the supposition, and had I not seen what I have detailed, I should at once set him down as an impostor, or at least the dupe of his own craft. Other objections will of course occur to your ingenious readers. My present business is with facts, and I should be glad to see from others a satisfactory theory on the subject."

There are several letters about its prevalence throughout

Somersetshire in "Notes and Queries," vol. X., 1854, and adjoining volumes. Some of the correspondents fancied it was an honest and true proceeding, and by tacking on to it the words "mesmeric influence" found it palatable enough for their mental digestion.

We may allude here to a point that seems not unworthy of mention. The dowsers whom we saw, held the rod downwards and caused it to turn *upwards* towards the face. Now in all the published descriptions which we have come across, the rod is held horizontally, and the sign of the presence of metals or water is, that it turns violently downwards, and points towards such. The theory being that the metal or vein exercised such a powerful influence over the twig as to attract it downwards. Now it is of course impossible, the bare mention of it is absurd, that up to this time metals or water should *attract* the fork, but that in 1873 it should *repel* the same; or that they should attract it in one place and repel it in another.

Such is a most incongruous result. It is quite certain that no one with any scientific training could receive such a theory for a moment.

In relation to this point we may quote Agricola who wrote in the begining of the 16th century. He gives a full account of the way the rod was used, and it is interesting as not only being an early but a clear history. We translate shortly some of his words.*

"There are many and great contentions about the forked rod; some say it is of the greatest use in finding veins, others deny it. Those who approve of it recommend a hazel twig, specially if it has grown over any vein.

Some use different woods for different metals, e.g. hazel for silver veins, ash for copper, fir for lead, a fork of steel or iron for gold.

The branches of the fork are held by the hands which are

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* G. Agricola. "De Re Metallicâ," liber 2.

tightly clenched; it is necessary that the compressed fingers should be turned upwards, so that the end of the rod may have free play: held thus, the diviner says when his foot is on the vein, that the rod immediately turns and betrays the vein, but that when he retreats it becomes immoveable again. Such affirm that the cause of the motion is the force of the veins, and that this is sometimes so great that it draws the branches of trees growing near the spot downward towards the vein: on the other hand those who deny that the rod can be of any use to an upright man, deny the power of the veins, and say it only turns with those who use incantations: specially they deny that a vein can draw down the branches of trees, and the twisting of these they refer to a hot and dry exhalation. To these the upholders of the rod answer, that if it does not turn with any man, it is due to some occult property in him which overcomes the force of the vein, which they affirm acts like a magnet. They remind us as to the way of holding the rod, that the fingers should be not loosely but tightly compressed, for if the rod be held loosely, it falls before the vein makes it turn: but when firmly held the attraction of the vein overcomes the force of the hands; and they hold five things essential for the manifestation—first, the kind of rod, because a vein won't act on one that is too big; second, the shape, unless it is forked it won't turn; third, the power of the vein; fourth, the way of holding the rod; fifth, freedom in the operator from any occult power which might counteract the force of the vein...........It is plain, however, why these fervid practitioners do not take a straight twig but a forked one, and that a pliable one, because if held firmly as they direct wherever you may be it shall turn; nor is it wonderful if it will not turn when held loosely...........The vulgar pin their faith on the power of the rod, because veins have been found in some cases, but much more often they cause the waste of fruitless labour."

He then points out what is plain to geologists, that by observing nature you can in many cases trace the metal-courses without a rod, or any incantation as he expresses it, or that a little "prospecting" will put you at once on the spot.

Agricola has shown fairly we think the absurdity of the supposed attraction of metal veins. We owe it no doubt to his scientific training as a physician that he gives us so minute an account of the diviners, and such a common-sense view of their pretentions.

Soon after his time it was put to far more chimerical uses than the finding of metals. To equal the senseless and impractical claims which some of its uses put forth we must turn to the extravagancies of modern spiritualists. Some pretended to discover whether one man had removed his neighbour's landmark; to show the place of concealment of stolen goods; to pick the thief out of a crowd; or to find the place where a murder had been committed.

Those who are interested in the subject will find some account of these diviners in an essay by S. Baring Gould, in "Curious Myths of the Middle Ages," where the information is of course second-hand, but it is a book easily accessible.

In Bayle's Dictionary, in a note to the article *Abaris* further information will be found. But the best book that we know on the subject is a little French work by M. Chevreul "De la Baguette Divinatoire, &c." Paris, 1854. He gives an account of most of these pretenders, and a short analysis of the books and pamphlets written on the subject during the middle ages. He shows how contradictory were the practices and claims of these diviners, (§ 236) but as we can only notice their geological pretentions, we must refer to M. Chevreul's book for further details.

The Coal Question.

BY E. TAWNEY, F.G.S.

Read at the General Meeting, April 3rd, 1873.

A ROYAL Commission was appointed in 1866 to investigate the probable amounts of coal contained in our known coal-fields, and also to estimate the quantity contained in probable coal-fields expected to exist but concealed under newer rocks, and also to report whether there was needless waste.

The main cause of the Commission of Enquiry being appointed was undoubtedly a book written by Prof. Jevons. In this he showed that our trade and manufactures were increasing at a rapid rate,—that these were entirely supported by our coal, and that the precious fuel on which all our commercial supremacy depends was being consumed (and much of it wasted) so fast, that there might probably come a great rise in price in coal and therefore of the iron, and hence too of all manufactured goods which would cause trade in these things to leave our shores: he argued that to the present time of prosperity would follow sooner or later one of commercial poverty: that our unfortunate descendants would find themselves obliged to migrate, "en masse" to the coal and iron mines of America, while those that remained would have the weight of our large national debt and very few resources to meet it. This book was referred to by statesmen in the debates of 1866 as a reason why we should diminish our debt, and the house agreed to a small measure of this kind.

It is not wonderful that Prof. Jevons' book should have attracted attention, for if he be right in his argument, there lies before us a stagnation of our trade, distress and emigration of our people, and such a rise of prices that we may be undersold in what is now our chief production, coal and iron. The report of the Coal Commission may then be looked on as giving us data by which we may examine the question. These data are of priceless value when we consider the importance of the issue at stake.

The greatest labour has been that of estimating the amount of coal in existing coal-fields. The coal-fields of the United Kingdom are thirty-seven in number—these are all separately calculated. Indeed, the labour of estimating the number of tons in a simple coal-field, like that of S. Wales is very considerable.

It is necessary to know the outcrop of each seam, in order to calculate its area: of course, owing to denudation, this is extremely irregular; a seam may be found on the N. side of the basin and not on the S.: again, it may thin out and be twice as thick on one side, and therefore give twice as many tons per acre: then the depth to which it goes must be ascertained, and the area of the same seam, above two thousand feet, has been calculated separately from the area over which it would be found plunging from two thousand to four thousand feet deep, or more. This is a very important element, for unless the seam is a good one there is very little chance of its ever being worked over two thousand feet deep. When the thickness and the area has been found, it is easily translated into tons, for a cubic yard of coal weighs roughly about a ton: so that a yard seam extending over a square mile would yield three million ninety-seven thousand six hundred tons, or in other words, a coal seam contains, roughly, a million tons per foot thick per square mile—of course a large amount of this is unavailable, being lost by faults, or barriers against water, or is left as supports and so on. Deductions are made for this, about a third of total amount; or (40 per cent. sometimes) is deducted by the commissioners.

The contents of the several coalfields stand thus in the Report, No bed less than one foot is reckoned.

		Tons under 4000 feet, after necessary deductions	Observations.
1	S. Wales	32,456,208,913	
2	Forest of Dean	265,000,000	
3	Bristol	4,218,970,762	
4	Warwickshire	458,652,714	All under 3000 feet
5	S. Staffordshire	1,906,119,768	
6	Coalbrook Dale & Wyre		
7	Clee Hills		
8	Leicestershire	836,799,734	Under 3000 feet, partly sub-Permian
9	N. Wales	2,005,000,000	
10	Anglesea	5,000,000	
11	N. Staffordshire	3,825,488,105	
12	Lancashire & Cheshire	5,546,000,000	
13	Midland	18,172,071,433	Eight-ninths of it under 3000 feet
14	Black Burton	70,964,011	
15	Northumberland & Durham	10,036,660,236	Partly over 4000 feet
16	Cumberland	405,203,792	
17 to 32	Scotland	9,843,465,930	
	Ireland	155,680,000	
		90,207,285,398	

In the known coal fields we thus have a total of ninety-thousand-million tons.

Though the commissioners have calculated all these tons as available, it must be admitted that in some cases a certain proportion is problematical.

Leaving the details of other coalfields, let us give a little attention to our own Bristol and Somerset Field.*

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* A map, similar to the diagram exhibited, has been published by Mr. Mc Murtrie in the proceedings of the Bath Archæological and Natural History Field Club. Vol. 2, part 4—1873.

This map seeks to show what would be seen if we could strip off the newer rocks so as to expose the coal measures beneath: it is further attempted to show the positions respectively of the lower coals; the pennant, or middle series; and the upper coals. The whole is seen to form one basin when the overlying rocks are removed; theory indicates this; on this alone we depend in parts where no pits have been sunk.

It is noticeable at once how much larger the concealed part of the field is than the part where the "measures" come to the surface.

Taking the figures of the Coal Comissioners, the area of the exposed portion is only 30,500 acres, but that of the calculated coal-field is 152,780 acres, or five times the visible coal field: of this however, 24,111 acres have been proved by pits and are being worked. Thus of the amount of coal put down by the commissioners to our coal-field, more than three-fifths of it is theoretical only, it has never been proved at all. Yet it figures in that part of the report which gives the available coal, and is not reckoned with the probable extensions of coal-fields which we shall come to presently. This seems to me a somewhat irregular way of proceeding, for until the beds are proved in one or two places over this large unexplored area, it is impossible to say how much may not be lost by faults and dislocations which carry the beds to unavailable depths. That there are dislocations seems to be acknowledged from the position of the seams in the Bishop's Sutton pit.

To estimate then the coal in the unproved portions of the field, the Commissioner has assumed the beds to continue without any dislocations, and has drawn theoretical sections from the outcrop of the Carboniferous Limestone and Millstone Grit which skirt the basin on the one hand, and the dips of the seams shown in the nearest pits on the other hand: all coal which is more than four thousand feet deep is not calculated. For instance, the numerous pits in the Radstock district are all in the *Upper* Coals, and below them at a depth of some eight thousand feet from the surface the *Lower* coals will be found. Of course at this depth they are quite unreachable, but toward the edge of the basin they would probably rise, and where they are calculated to come within four thousand feet of the surface they begin to figure in the returns.

So much for the method of estimating the supply which is proved, or theoretically supposed to exist for us, in our Bristol coal fields.

The total thickness of the measures is about eight thousand feet, that of the productive part being about five thousand feet. There is an average of thirty-five seams of coal, with an aggregate thickness of sixty feet.

The length of the basin is twenty-six miles from the Mendips to Cromhall Heath, and its greatest breadth is twelve miles, viz., from Bristol to Twerton. The number of collieries working is about forty-five. Many of the seams included by the Commissioners, who count all seams above a foot, are too thin to be worked except at very shallow depths, and under favourable conditions; it will be necessary therefore to strike off a certain proportion of their gross estimates,—probably a twentieth of the whole must be deducted for this reason.

We may now turn to that part of the Report which deals with the probability of finding coal under the Permian, New Red Sandstone, or other superincumbent strata. This is drawn up by Professor Ramsay, and the evidence is nearly entirely supplied by the officers of the Geological Survey. Here again our interest is excited by finding that Bristol figures in the list of probable new coal-fields. The position of these "pastures new" for our voracious engines, is along the banks of the Severn, from the New Passage to near the mouth of the Avon.

An anticlinal of Carboniferous Limestone and Millstone Grit which rises to the surface, suggested so long ago as 1824 to Buckland and Conybeare, the likelihood of the over-lying productive measures being concealed in this district by the New Red Sandstone and surface deposits. In making the South Wales

Union Railway, coal seams were actually found, so that productive measures probably lie over a tract of eight miles long, by five and a half broad. The area of this little probable field is forty-five square miles, and the Commissioners put the probable amount of coal in it as four hundred million tons.

As the overlying rocks are known to be thin here, one almost marvels that no one has explored this ground; but there is little doubt that if coal were to rise permanently in price, many of these new fields would be tested by explorers.

The most important of these extensions of coal-fields is that supposed to exist on the east of the Notts and Yorkshire fields: it is not only by far the largest, but is perhaps one of the most certain to be reckoned on. The Commisioners estimate the area of new fields here at nine hundred square miles, and the probable amount of coal in this theoretic extension is put at *twenty-three thousand million* tons, an enormous quantity, almost one half the whole amount which they count on from the new coal-fields. The whole of this is estimated to lie at not more than four thousand feet deep, and therefore no physical reasons would prevent its being reached, while perhaps almost half of it would be under two thousand feet deep.

There is a large area round the South Staffordshire fields which probably contains coal measures under the newer rocks; the probable depth to which these measures attain is carefully considered, and the probable amount of tons to be found under four thousand feet is given as follows:—

Between South Staffordshire and Warwickshire, (after the necessary deduction of forty per cent.) three thousand four hundred million tons.

Between South Stafford and Shropshire, (after the necessary deduction of forty per cent.) five thousand eight hundred million tons.

Between South Stafford, Coalbrookdale, Cheadle, and North Staffordshire, (after the necessary deduction of forty per cent.) four thousand five hundred and eighty million tons.

In fine, the total amount of probable available coal in the theoretic extensions, or new coal-fields in the United Kingdom, is given as FIFTY-SIX THOUSAND, TWO HUNDRED AND SEVENTY-THREE MILLION tons, or more than half what still remains in the known proved coal-fields,

These are the figures of the Commissioners. In speaking before of the Bristol field, I suggested that a large proportion of the amount counted in the proved list ought to be transferred to the problematic: problematic, not that it did not exist once, but because it is not proved to be in a position or state that will ever pay working.

Leaving now the estimates of coal which remains for future supply, and the means by which these data are obtained, we will turn to the question of the so-called *duration of our coal-fields.*

This is the main purpose for which the Commission was appointed, and the collection of the enormous mass of important data at which we have merely just glanced, was framed entirely with a view of knowing what relation our *future probable supplies* bore to our *actual annual consumption.*

It is admitted by every one, without exception almost, that our prosperity depends entirely on our coal. It is coal which is the source of all our manufactures, either directly or through the cheap iron which it gives us; it is by the cheapness of our manufactured cotton and wool stuffs, our rails, and machinery, that we undersell other nations, and obtain our immense trade; it is the cheapness of our coal which enables it to be used as freight instead of ballast in outward-bound vessels, and by adding to the profits of the voyage, causes a large accession to our trade; it is the cheapness of our coal which indirectly enables us to do most of the carrying trade of the world.

Cut off the supply of coal, or what comes to the same thing, let the price be raised, so that instead of being cheaper, it is as dear or even dearer than the coal of one or other nations, and the picture must be reversed. Our prosperity and our trade will take to themselves wings and flee to that nation where coal is the cheapest.

We may then say, that this is indeed a *burning* question. Compared with this, the changes of ministry; questions as to whether a man may call himself educated while ignorant of Modern History and Philosophy, sink into the merest insignificance.

In reading the remarks of the Commissioners on the duration of our coal, we must remember that it is framed with a view of meeting or allaying the alarming fears which were justly excited by Professor Jevons' book.

We may therefore read over again Professor Jevons' argument by the light of the data collected by the Commission.

The annual consumption of coal is continually increasing. If it were constant it would show that our trade was stagnant, and that some cause or causes were keeping down the natural increase of population. But this is not so, and never has been since the invention of the steam-engine and the rise of modern manufactures and general use of machinery. It has not been so in England, neither has it been so in any coal-producing country that we know of.

Since 1854 the amount of coal raised has been ascertained by a Government Department attached to the Geological Survey, viz. :—the Mining Record Office.

The statistics since 1854 are therefore accurate; before that we have nothing but more or less inaccurate guesses. It is supposed that about 1781 the coal raised was a little over five million tons; about 1801 it was ten and a quarter millions, thus nearly doubling itself in twenty years. This was owing to Watts' invention of the steam engine, and the modern iron smelting by coal; from which time we may date the wonderful gradual improvements in arts and manufactures.

In 1821 it was about twenty and one-third millions, almost doubling itself again in twenty years, as far as we may rely on these estimates; 1841 it was about forty and a half million, again nearly doubling itself. The coal raised in ten years, between '54 and '63, was half as much as in all the previous seventy-two years. From 1854 we know precisely the annual rate of increase: in 1854 it was sixty-four and a half million tons; in 1874 it will be nearly double that, we can safely predict; for though the last published returns only are for 1871, still at that time the annual yield was one hundred and seventeen and one-third millions; and knowing the annual rate of increase, it will be fully one hundred and twenty millions in 1872;* in 1873 it will be nearly one hundred and twenty-four millions; and in 1874 it will be over one hundred and twenty-seven, or nearly double the sixty-four and a half millions it was twenty years before.

It was Professor Jevons who first showed the annual increase was not simply an addition in arithmetical ratio, but in a geometrical ratio. It increased something like a sum at compound interest increases differently from one at simple interest. Writing in 1865 from the ten years that were known, he obtained the rate of increase, and from that he calculated forwards how much coal would have been consumed in the next one hundred and ten years from that time. And he came to this remarkable result,—that by the end of that time, if our prosperity held, we should have used all the available coal that was known to be within reasonable depth, *i.e.*, within four thousand feet. This was a prospect that struck many with alarm, and coal owners in particular were unwilling to accept either his argument or conclusions. The greater part however of his opponents, as he says in his second edition, misunderstood him; others actually conceded the points which he was endeavouring to prove without foreseeing the conclusion it led to. Some disputed that the rate would continue to increase as it had done; some great authorities writing several years after Professor Jevons, were of opinion that the output would never go beyond one hundred and fifteen

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* From the "Mineral Statistics" for 1872, (published December, 1873) it appears that the coal raised amounted actually to 123,497,316 tons.

millions. It already reached one hundred and seventeen in 1871.

I think you will admit that great weight must be given to Professor Jevons' calculation, for the following reason. When he wrote, the last and greatest annual yield was ninety-two millions, viz., that of 1864. He calculated that in 1871 the annual consumption would be 117.9 millions. Now that 1871 has passed we can estimate the value of the prophecy made seven years before-hand. The prophecy gave nearly one hundred and eighteen millions; the actual fact was 117.35. His estimate was nearer by four millions than the one which his most liberal opponents stood out for. But Professor Jevons complains that he never said our coal would be exhausted in one hundred and ten years. The whole argument of his book goes to prove that something else might possibly happen, something more disastrous, namely, this: that this yearly rate of increase could not continue, that prices must rise, that it would not pay to sink deeper mines, that as our shallow mines got worked out our prosperity would decline, and we should never have an opportunity of reaching those valuable stores of coal which we know to be beneath us. Looked at from this point of view it is as much as anything a question of price. It is the present prosperity which will gradually work its own death, by raising the price, owing to the deepening of the mines and the working out of the more superficial seams. Perhaps the following sentence may serve to propound his view; he quotes it himself from a Committee on Coal Mines in 1843: "When the expense of working British coal mines leaves no remuneration to the capital and labour employed, when brought into competition with the mines of other countries, then will they be as effectually lost to Britain for purposes of ascendancy, and their produce as exports, as if no longer in physical existence; and her supremacy in the mechanical arts and manufactures, it may be feared, will be superseded."

We have therefore come to this point of the argument,—that there is something as important as the amount of coal for future supply, and that is the price at which coal can continue to be offered. We must therefore glance at the causes on which price may be imagined to depend. We may put these under the heads of annual requirements and foreign competition. Professor Jevons argues that so long as our prosperity holds, our population must continue to increase, and every increase of population necessitates a multiplied increase in the consumption of coal; the large consumption of coal necessitates deepening the mines; this largely increases the expense of the coal, and hence of all costs of living in this country. From that follows increased emigration to America. Now the coal of America is so vastly beyond ours in amount, and so near the surface and so easily worked, that when the population is a little thicker there, it will probably undersell our coal, and the bulk of the iron and coal trade must go over to America, he argues, and with it finally our population. What we have possibly to look forward to then, according to him, is for some time a continued increasing prosperity of our country, with increasing trade and increasing consumption of coal; but subsequently such a rate of prices as will be prohibitive against raising our deeper supplies, while capital and labour will take themselves off to the larger and cheaper stores of coal elsewhere.

I hold Professor Jevons' argument unanswerable so far, that continued prosperity entails a constant increase of population; an increasing population requires increasing amounts of corn for food; this corn has to be brought from foreign countries, and is paid for by the manufactured goods,—iron and other staples of our trade; all these depend upon and mean increased coal consumption, besides the increased domestic demand for an increasing population.

It is well known that many of the best seams are getting worked out over the areas of less than two thousand feet deep; yet the deepest coal mine in England is only two thousand four hundred and forty-five feet: it was sunk to win a seam of special fine quality, which bears a fancy price in the market. With the present prices these deep pits would not pay for ordinary seams. It is said that a pit over two thousand feet deep adds thirty per cent. at once to the expenses. Before deep pits can be generally sunk, prices must rise considerably. A rise in price exposes us to be undersold if there is any country where coal is likely to be cheap. We must therefore glance at the chief coal producing countries. The merest rules of ordinary prudence compel this.

It is by no means the case that England is the only coal producing country in Europe.

France has several detached fields, and raises about one-ninth what we do in England; but the inland carriage is so high that we undersell the French coal all along the coast. The fact that our coal fields are mostly on the sea-shore is one of the great items in our favour.

Belgium raises almost as much; the price there is high—about twenty shillings a ton at the pit's mouth; and of course it must progress like our own.

Prussia contains some very valuable fields; they are far richer than any of our English fields as far as thickness of coal is concerned, but most of it is so deep that it will never be available. However, there seems to be about forty million tons within reachable depths.

Silesia contains a field which is said by geologists of reputation to contain fifty million tons within depths that have been already worked elsewhere, about one-third of the whole supply which the Commissioners give for the United Kingdom: it will therefore outlast all but our best coal-fields.

The resources of Russia are uncertain, but it is said that there is coal over an area of twenty thousand square miles * The area of our proved British coal-fields being a little over five thousand, five hundred square miles.

But it is when we turn to the United States, that we see, perhaps, the coal-fields of the future. It is probable the main coal and iron trade of the world must eventually be concentrated

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* Coal and coal-mining, by W. W. Smyth. p. 86.

there. The area of the United States fields is about thirty-five times that of Great Britain. In the Pennsylvanian field, one seam from eight to fourteen feet thick is traced over fourteen thousand square miles. The great thing in favour of the United States fields, is the regularity and horizontality of the beds. Sir C. Lyell has described how the seams may be seen cropping out along the banks of the Ohio perfectly level for miles. On the other hand, the great price of labour in that country prevents their being worked, so that now English coal competes with American successfully along their sea board—until their coal-fields have been better proved, until it is shown that the thickness of coal vertically is at all commensurate with the enormous area of the measures, it may possibly turn out that the price will never be so low as some would have us believe. But from all appearances it seems that it will never pay English capital to be exerting itself on mines over two thousand feet deep, when there are such vast stores nearer to the surface in America. However, the growth of population in America, and the cheapening of the labour there, is what is essential before the American coal can compete with ours for the present.

If we turn to the Report of the Coal Commission, we find little or no information on the subject, they ignore the subject of foreign competition; failing to entertain a very important half of the question, they really afford us very little means of judging how long our supremacy in coal may last.

Thus they fail to meet Prof. Jevons' argument almost entirely. They show, (supposing no competition of a cheaper coal interferes,) that we have enough coal to last a very long time. But this is to take for granted almost the very point on which we have misgivings. They give us three alternatives for the duration of our coal.

The *first* is framed on the relation of population to coal consumption. The consumption of coal per head of population increases every year, but according to the Commissioners it is a diminishing rate of increase; they also calculate that though the population increases annually it is also at a diminishing rate. On these assumptions they calculate that our coal will last three hundred and sixty years.

The *second* alternative is to take a constant annual increase of three million tons. On this supposition our coal would last two hundred and seventy-six years—this has been already falsified, for the very first year after the Report, the annual increase was seven millions. We can therefore scarcely accept this with any confidence.

There remains the *third* alternative, that is, that the yield should remain constant and not increase from year to year, taken at one hundred and fifteen million tons it would last one thousand two hundred and seventy-three years—this again is open to the same retort, that the first year the returns were increased to one hundred and seventeen and one-third. At this rate it would last only one thousand one hundred and sixty-three years. There are other reasons why these two latter estimates cannot be accepted.

If the country is to continue prosperous, it seems impossible but that the population should increase from year to year in a geometrical ratio, and if so, it is absolutely impossible but that the coal consumption should do similarly. If the population only increases by a constant increment every year, that shows that the prosperity is slowly declining; capital must seek employment elsewhere, and probably might assist in developing the American coal-fields, and so bring on the contingency which we fear, quicker even than a time of larger coal consumption: the increased emigration would have the same effect.

What seems most desirable is that we should go on prospering and increasing our coal consumption and holding our supremacy as long as we may, but it seems probable that there will come a time when our coal getting dearer and dearer, our trade will gradually become stagnant, and next diminish; our population must then remove to America and Australia, capital will follow, the coal-fields of these countries will be opened up, our manufactures will eventually almost cease, and we shall relapse into the agricultural people that we were formerly.

Illustrations of the Zoological Department of the Bristol Museum.

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

Mr. Swayne having on a former occasion read a paper on the Anthropoid Apes, the Gorilla, Chimpanzee and Orang, now described some other typical forms of the Quadrumana, viz., the Gibbons, the Spider Monkeys, and the Loris, illustrated by specimens from the Museum, three of these being recent additions to the collection.

The first of these, the Gibbons, like the Anthropoid Apes, are destitute of a tail, but in the Spider Monkey this organ is perhaps its most important characteristic. In the Anthropoid Apes we found an absence of callosities on the hind quarters; and in the Gibbons they are present only in a very slight degree; whilst in the Baboons they are a very striking feature. Like the Anthropoid Apes, the Gibbons seem capable of assuming the erect posture, although with difficulty. In comparing the relative length of the arms with that of the whole body, we find that the Gibbons exceed the Anthropoid Apes in the length of this member, as the fingers touch the ground when the creature is erect. The generic name of the Gibbon, "Hylobates," or "Tree-goer," seems very suitable to its habits of taking long bounds from tree to tree in its native forests.

The characters are—

"Head very small, feet long, hands touching the ground when erect, no tail, skull flat with large orbits, teeth thirty-two, as in man and the apes, upper canines very large; body covered with dark hair, differing in the several species and at different ages."

The species described are—

H.—Agilis, or Variegatus, from Sumatra, called "Ungkaputi" by the natives.
H.—Syndactytus, or "Siamang," from the Sumatsh.
H.—Lar, or Albimanus, from India and Malacca.
H.—Hooluck, from Assam.
H.—Concolor, from Borneo.
H.—Leuciscus, from Java, called the "Wow-wow."

Of these perhaps the first and second are the best known.

Of the two exhibited, the larger appears to be H. agilis; the smaller may probably be H. Hooluck, although its markings agree with the male H. agilis, it came from Nepal. The H. syndactytus, or Siamang, is remarkable for having the first and second fingers of the hind limbs joined by membrane as far as the middle of the second joint; it has also cheek pouches. The name "Wow-wow" given to H. leuciscus, is descriptive of its peculiar loud cry which is uttered especially towards morning, and can be heard at great distances. In a room it is described as somewhat deafening. Mr. J. G. Wood describes the musical characters of the cry of one species at considerable length. During the uttering of a series of these cries, increasing in intensity, the whole body was seen to be in a state of excitement, lapsing into quietude at the close of the performance. Their manners when domesticated appear to be gentle, and they are capable of attachment to man.

In the Gibbon, besides the greater length of the arms, the thumb is not truly opposible as in the apes. The chest is large, indicative of the activity which is so characteristic of these creatures, and which is so great as to enable them to swing themselves over spaces of thirty or forty feet from one tree to another.

The special characters of H. agilis are "Face, blackish-blue in the male, brown in the female; in the male, a white band over the eyes, which unites with the whiskers; hair fine, except about the neck, where it is longer and a little woolly; upper part chocolate-brown; back and fore part of thigh yellowish-brown, but the color varies according to age and sex, the young being lighter colored; height about two feet seven or eight inches; no guttural sac."

Of the two specimens exhibited, the larger lived for some time in the Clifton Zoological Gardens; the smaller was brought to this country from Nepal, by Captain Gimblett, now of Clyde Road, Redland. He obtained it alive in 1845, it was then nine months old. He endeavoured to bring it to England by long sea voyage in 1846, but it got pneumonia in the cold weather, and died in the Channel just before reaching England. It was thus four months alive in his possession. Captain Gimblett describes it as very intelligent and affectionate: in the morning when he went to its hut on board ship, he describes it as greeting him almost with a smile. It was fed chiefly on boiled rice and milk. On arriving he showed its skin at the Zoological Society in London, and he was then and there offered £50 for it.

The Spider Monkeys belong only to the American continent, and are included in the family of Platyrhines or Cebidæ. The generic name "Ateles," means "imperfect," and is given on account of the almost complete absence of the thumb or hallux. They are long-limbed and active creatures, but unlike the Gibbons, the legs are as long as the arms. But the special character of the Spider Monkey is the remarkable tail which quite serves as a fifth member, and is provided with a firm elastic band at its under part, which enables it to hold so strongly to the branches of trees, as not even to loose its hold after death. Their tails are described as possessing very delicate touch, and are even used for seizing small objects. The Spider Monkeys are met with in great profusion in their native woods, where they may be seen hanging from the branches like clusters of fruit. They are described as often remaining motionless for hours, although capable of moving with great activity. They are destitute of cheek-pouches, and their teeth are thirty-six in number instead of thirty-two, which is the number for the higher apes and man. The nostrils open at the sides, whence the name Platyrhine given to the family. Several species are described differing somewhat, but chiefly of dark or jet black color, with longish hair.

The Loris belongs to another family of the Quadrumana, viz., the Lemuridæ. The true Lemurs are inhabitants of Madagascar, where they appear to replace the Monkeys. In the Lemuridæ all the feet have five fingers, the fourth being the largest. The hind feet are longer than the fore feet; all the nails are flat except that of the second finger, which is narrow and hooked like a claw.

The genus Loris contains some curious animals which differ from the true Lemurs by the almost entire absence of a tail; whereas in the Lemurs this organ is long and bushy.

Of the two species of Loris, the limbs are delicate and slender in the L. gracilis, while in the present species L. tardigradus, or Kukane, they are somewhat more heavy. Mr. Bennett, in his "Gardens and Menageries," says, "Its proportions are short and thick set, and the apparent clumsiness of its form is much increased by the manner in which it usually contracts itself into a ball. Its head is broad, flat, and rounded with a slightly projecting and pointed muzzle, in which the nostrils are perforated laterally. Its eyes are large and perfectly orbicular, and furnished with transverse pupils capable of being entirely closed during the day, and of being very largely dilated at night: their inner canthus is situated so low towards the nose, that the motion of the eyelids appears to take place in a diagonal instead of a horizontal direction. The ears are short, round, and widely open, but buried in the fur, and the tail is merely a rudiment of a few lines in length. The hinder limbs are considerably longer than the fore. The whole of the body, with the exception of the muzzle is thickly set with long close woolly hair of a gray-brown color. A dark band passes along the back, and divides on the head to enclose the eyes and ears, leaving white patches on the forehead, and none over the eyes. On the under surface the fur is lighter colored than above. The dentation of the Loris differs from that of the true Lemurs in there being six instead of four lower incisors, which are placed horizontally. Of the four upper incisors, the middle ones are large and the lateral ones excessively small. The canines are somewhat turned outwards. There is one molar less on each side of the lower jaw than in the upper where there are six. The total number, as in the true Lemurs, is thirty-six.

Sir Anthony Carlisle having noticed in this animal a peculiar distribution of the blood-vessels of the arm-pit and groin,—twenty-two equal-sized trunks passing off from the main vessel to be distributed to the muscles—considered that this peculiarity might be connected with the slow stealthy movements of the creature.

Mr. Wood, in his entertaining Natural History, has described very picturesquely the habits of the slender Loris. He says that these nocturnal animals steal upon their prey, which is commonly small birds, by very gradual noiseless movements, and seize it at last by a sudden snatch as rapid as the previous advance was slow. Its great powers of vision at night would seem especially suited to their habits.

In captivity the Loris appears to be tolerably omnivorous, and has a habit of clutching its food first with both hands, and then transferring it to the left before eating it. It is, as might be expected, a very silent animal, never making a sound except when irritated, and then only a low plaintive cry.

On an occurrence of Filaria Gracilis found in connection with the Great Omentum of a Spider Monkey.

BY S. SMITH, M.R.C.S.E., and L.S.A.,

Read at the General Meeting, October 2nd, 1873.

It will not be necessary for me in this place to enter into an elaborate anatomical description at large of these animals; I shall therefore simply say, that under the term Annulosa, or Worms, Zoologists comprehend—

1. Entozoa, or Intestinal Worms—animals in which segmentation is not very distant.
2. Rotifers.
3. Turbellarias, and
4. Annelids.

Entozoa, which live upon the secretions of other animals, are sub-divided into Cestoid, or flat worms, in which there is neither mouth nor stomach, to which order Tape-worms and Cystic Entozoa belong; and Nematoid, or round worms, in which order are to be found Lumbrici, Thread-worms, Filaria, Dracunculus, &c., &c., and to which the specimens before us properly belong. The third division is called the Trematode group, of which the Fluke, so often found in the liver of sheep, is an excellent example. We may observe further, that Entozoa are furnished with assimilative, excretory, and generative organs; that they are possessed of imperfectly developed nervous and circulatory systems; and lastly, that peculiarities in the form of individual members of the several groups, are sufficiently striking to enable us in some cases, by the eye alone, and in others by the aid of the microscope, to distinguish, not only between species, but individuals of opposite sexes.

We have ascertained then that the worms before us belong to the Nematoid or round worm order; and we shall see presently that they more particularly pertain to the genus Filaria,—they are indeed fine specimens of the *Filaria gracilis*, a variety discovered long ago by the celebrated helminthologist, Rudolphi, whose work, written in the Latin tongue, is contained in the library of the Microscopical Society in this Institution; and with the exception of the differences in the length of these specimens and those described by him, together with two tubercles, situated not upon the head, but near the extremity of the tail, his description tallies with the result of my examination. Owing to these differences, and never having seen on any former occasion a worm of this species of the great length to which these have attained, I forwarded one of them to Professor Spencer Cobbold, of London, who kindly replied to the effect that they were specimens of *Filaria gracilis*. The following description will apply, except as to length, to all the specimens freed from the peritoneum.

Male worms. Length of the worm, minutely examined, twenty-seven inches. It tapers from the middle to each extremity, terminating abruptly at the head, which is conical, depressed, and without tubercles, the tail being elongated, pointed, and twisted several times upon itself; outer covering of body exceedingly transparent, arranged distinctly in circles, reflecting generally an emerald green light. General substance of body semi-transparent, its caudal portion transparent throughout its entire length. Layers of longitudinal muscular fibres can be distinctly seen beneath the integument. Mouth, a simple circular opening, no papilla being visible around it. Æsophagus, stomach, and intestinal canal plainly descernible, continuous throughout.

The instances of this variety observed by Rudolphi, were discovered within the peritoneal folds of a Capuchin Monkey, but their exact locality is not mentioned. He also discovered Filaria in the Aard Wolf, an animal intermediate between the Hyæna and Civet. In respect of those discovered in the Monkey, he describes them as hermaphrodite, which does not accord with my observation in this case.

Having now determined the species and named the worms, we may with propriety consider—

First,—The form and manner in which the worm obtains admission into the body; and

Secondly,—The most probable manner in which the worms before us managed to reach the places within the folds of the great omentum, which, hanging from the stomach, covers the intestines, and by folding returns upon itself, consisting at this part of four layers of serous membrane.

Now as to the first consideration. A worm may obtain admission into the body, say the human body for example, either in the form of an egg, or as the product of an egg; or again, they may enter *per ora*; or, as in the case of the Guinea worm, and some others of the same class, they may perforate the skin. Take for instance the case of a Lumbricus, although it has been hotly disputed, yet there appears to be but little doubt that this animal obtains admission into the system in the form of an egg, which has passed away from the body of an intestinal worm situate at the time in the intestine of some unfortunate individual; such an egg dried by exposure to the atmosphere may be blown about by winds, and deposited upon a vegetable, which, conveyed to the mouth of some unlucky wight, the egg escaping the effects of the teeth, passes direct to the stomach, and thence to the intestine, where it developes into a worm, to repeat the process of generation, expulsion of ova, and return to the system again. Let us now see how this matter is managed in the case of the Tape-worm: here the process is not quite so simple, for the process of metagenesis, as it is called, holds among Tape-worms; according to this law, the father does not resemble the son, neither does the son again resemble his son, but the son's son resembles the grandfather, so that the egg of the Tape-worm may find its way into the system as in the case of the round worm, but here we have—

1. The egg.
2. The larva, or embryo.
3. The further developed larva, or Cysticercus cellulosœ, constituting the "measles" in pork.
4. The undeveloped Tape-worm.
5. The truly developed Tape-worm; and
6. The egg again, thus completing the cycle of generation, expulsion of ova, and admission into the body as before.

Let us now consider

Secondly,—The manner in which these worms before us obtained admission into the peritoneal sac; and by the light of previous remarks bearing upon this part of the subject, I trust we shall see our way clearly to a right conclusion.

Now Dr. Watson, in his valuable work on "The principles and practice of physic" in respect of this matter, in the case of Lumbrici, and I believe Ascarides also, details instances in some degree resembling the case with which we have to deal, in which he states that Lumbrici have made their way into the peritoneal cavity, or great cavity of the abdomen, and also into the bladder and other parts of the body otherwise than their usual habitat; and, contravening the vulgar opinion that the worms had eaten their way through the coats of the bowel, he expresses his belief that they have passed through accidental openings, *e.g* , fistulous passages, the result of ulceration followed by perforation of the walls of the canal or viscus; he does not, however, state definitely where these passages existed, nor does he say in what part of the peritoneal cavity the worms were found; neither does he affirm that those openings were actually discovered; that such might have been the case we cannot for a moment doubt; but in the case before us, after carefully examining the stomach and intestines, I was unable to discover any abnormal opening, nor did these viscera to my surprise contain worms of any kind. After examining them again very carefully without finding worms or perforations, I removed the stomach, but did not at the time think it worth while to preserve the intestines, a circumstance which I now greatly regret. The stomach, however, as you observe in the specimen, floats in the spirit and water, and being distended with air, it proves the integrity of its coats to be perfect. Whilst engaged in exploring the omentum however, I observed a worm lying in immediate connection with a lymphatic gland, situate near the great curvature of the stomach, towards its pyloric extremity. The gland appears to form one of the third group of lymphatic glands which run along the great curvature in connection with the right gastro-epiploic vessels which empty themselves at the root of the mesentery into one of principal lacteal vessels; and this worm, I am happy to say, is to found in the preparation before you. Now under these circumstances, as the coats of the stomach and intestines were entire, and we have this worm in immediate connection with the gland, for it appears to be partly within and partly without it, I do not see how we can avoid coming to the conclusion, startling as it may appear, viz., that the ova or minute embryo of the worms found, (for there are several) obtained admission into the openings of the lmyphatic vessels situate in the submucous tissue of the stomach, or into the open mouths of the lacteals of the intestines, and developing there, escaped by ulceration of the gland substance into the peritoneal sac, where they were in this instance discovered.

It appears from enquiries instituted, that the symptoms evinced by the unfortunate animal from whom these worms were taken, were not of such a nature as to give rise to any suspicion of their existence in its body, neither did the post-mortem examination, as might have been expected, reveal anything of inflammation or its effects upon the serous membrane in which they lay, nor did death result from their presence, so that we are presented with the singular spectacle of an animal harbouring such apparently formidable enemies to its personal comfort, and these again perilously situated as to the life of the animal, without offering any symptom in particular to indicate their presence, much less their actual locality.

Desmidieae, observed in the immediate neighbourhood of Bristol.

BY W. W. STODDART.

Read at the General Meeting, November 6th, 1873.

ALTHOUGH the Desmids do not like a limestone soil, yet the following list of these beautiful forms proves that the Bristol naturalist has a tolerably fair field for his searching powers.

Although rarely found in running streams, yet one or two may be gathered in such a habitat—as Closterium Ehrenbergii, &c. Generally, however, the most likely spots are small holes or shallow ditches exposed to the light, especially in grassy situations. One invariable *sine qua non* is that the water shall be bright and clear.

The best method of collecting Desmids is to have a small oval strainer with a fine cambric bottom. Sometimes a tin scoop is preferable, when the Desmids are much diffused, and straining the water through fine muslin or cambric stretched on a flannel. The little bodies can then be scraped off with a knife and transferred to the usual wide-mouthed bottle. Many species are usually found as a cloud on the leaves or stems of submerged plants. In this case considerable care is required, lest the group be lost by diffusion through the surrounding water.

When the specimens are wished to be mounted for the cabinet the best preservative solutions are aqueous solutions of kreosote or carbolic acid. In the author's opinion, the best way is to employ preservative gelatine. They are thus preserved in a perfectly natural manner, without any danger of leakage, a result that is so often an occurrence in the cabinets of the most careful and experienced microscopists.

With these few observations, and the following catalogue of localities, it is hoped that the members of the Society will find less difficulty in their search for specimens of these wonderful and incomprehensible organisms.

Arthrodesmus convergens, (Ehr.)
Ditches at Henbury, Yate Common; the Water Works Reservoir, on Durdham Down.

Arthrodesmus incus, (Bréb.)
Back of Redland Court; Yate; Westbury.

Closterium lunula, (Müller.)
Fields near the New Passage; Cross Hands; Fields near Chilney Springs; Reservoir on Durdham Down.

Closterium acerasum, (Schrank)
Side of Railway near Patchway Station; Ditches at Shirehampton; Aust.

Closterium costatum, (Corda)
Stapleton; Portskewet; Leigh; Bedminster.

Closterium didymotocum, [var. Baillyanum,] (Bréb.
Under Penpole.

Closterium Ehrenbergii, (Menegh.)
Ashley Brook.

Closterium Leibleinii, (Kütz.)
Shirehampton; Pilning; New Passage.

Closterium moniliferum, (Borg.)
Stapleton; Bedminster; Horfield; Over.

Closterium rostratum, (Ehr.)
Barrow Reservoir; Durdham Down, near the Blackboy Quarry; Westbury; Stapleton Quarry.

Closterium striolatum, (Ehr.)
Thornbury; Stapleton Quarry.

Closterium setaceum, (Ehr.)
Ashton Park; Saltford.

Cosmarium attenuatum, (Bréb.)
Lamplighters.

Cosmarium bioculatum, (Bréb.)
Wickwar; Bedminster.

Cosmarium Botrytis, (Bory.)
Stapleton; Charfield.

Cosmarium Bromeii, (Thwaites)
Ditches at Shirehampton.

Cosmarium curtum, (Bréb.)
Lamplighters.

Cosmarium cucurbita, (Bréb.)
Meadows at Bedminster; Ashton.

Cosmarium cylindricum, (Ralfs)
Side of well, near second bridge at Stapleton; Over.

Cosmarium commissurale, (Bréb.)
Under north side of Dundry Hill.

Cosmarium cucumis, (Corda)
Stapleton; Brislington.

Cosmarium crenatum, (Ralfs)
Bedminster; Yate; Fishponds; Stapleton Quarry.

Cosmarium granatum, (Bréb.)
Bedminster.

Cosmarium margaritiferum, (Turpin)
Stapleton; Brislington; Fishponds; Bedminster; Chelvey.

Cosmarium ornatum, (Ralfs)
Road-side ditch, Shirehampton.

Cosmarium Thwaitesii, (Ralfs)
Shirehampton.

Cosmarium tetraophthalmum, (Kütz.)
Duchess' Pond, Stapleton; Chelvey.

Cosmarium undulatum, (Corda)
Stapleton.

Desmidium Swartzii, (Ag.)
Stapleton; Filton.

Docidium baculum, (Bréb.)
Stoke Bishop; Charfield; Brislington.

Docidium nodulosum, (Bréb.)
Durdham Down, east side; Leigh; Westbury; Failand.

Euastrum ansatum, (Ehr.)
Under Dundry Hill.

Euastrum binale, (Turp.)
Damory Bridge.

Euastrum didelta, (Turp.)
Stapleton; Durdham Down Reservoir.

Euastrum elegans, (Bréb.)
Yate; Fishponds.

Hyalotheca dissiliens, (Smith)
Stapleton; Yate.

Hyalotheca mucosa, (Mert.)
Avening Green.

Micrasterias denticulata, (Bréb.)
Bedminster; Dundry; Yate; Durdham Down Reservoir.

Micrasterias rotata, (Grev.)
Durdham Down Reservoir.

Micrasterias truncata, (Corda)
Bedminster; Ashton.

Pediastrum ellipticum, (Ehr.)
Stapleton Quarry.

Penium Brebissonii, (Menegh.)
Horfield; Bedminster; Chelvey; Damory Bridge; Duchess' Pond.

Penium digitus, (Ehr.)
Avonmouth; Stapleton; Bedminster; Chelvey; Bitton.

Penium margaritaceum, (Ehr.)
Ashley Vale: Horfield; Leigh; Stapleton.

Penium ?
This specimen was found in the Reservoir, Durdham Down. It had rounded ends, but *without markings*, probably an empty frond.

Scenedesmus acutus, (Meyen)
Hanham.

Scenedesmus dimorphus, (Turp.)
Stapleton; Nailsea.

Scenedesmus obliquus, (Turp.)
Stoke Bishop; Ashton.

Scenedesmus obtusus, (Meyen)
Leigh; Stapleton; Horfield; Ashley Vale; Hanham.

Scenedesmus quadricauda, (Turp.)
Stapleton; Bedminster; Reservoirs at Barrow and Durdham Down; Shirehampton.

Sphœrozosma excavatum, (Ralfs)
Bedminster.

Spirotœnia condensata, (Bréb.)
Ashley Brook; Stapleton; Bedminster.

Staurastrum alternans, (Bréb.)
Bedminster; Horfield.

Staurastrum asperum, (Bréb.)
Bedminster; Yate.

Staurastrum brachiatum, (Ralfs)
Barrow.

Staurastrum cyrtocerum, (Brèb.)
Stoke Bishop.

Staurastrum controversum, (Bréb.)
St. George's; Yate.

Staurastrum dilatatum, (Ehr.)
Stapleton; Yate; Kingsweston.

Staurastrum dejectum, (Bréb.)
Mangotsfield Common; Yate; Brislington.

Staurastrum hirsutum, (Ehr.)
Yate; Stapleton.

Staurastrum margaritaceum, (Ehr.)
Wells; Aust; Glastonbury.

Staurastrum paradoxum, (Meyen.)
Leigh; Avonmouth Gardens.

Staurastrum sex-costatum, (Bréb.)
Yate; Leigh; Glastonbury.

Staurastrum tetracerum, (Kütz.)
Avonmouth; Yate.

Tetnemorus granulatus, (Bréb.)
Hanham; Kingsweston.

Tetnemorus Brébissonii, (Menegh.)
Durdham Down Reservoir.

Xanthidium armatum, (Bréb.)
Oldbury Court Woods.

Xanthidium aculeatum, (Ehr.)
Charfield ; Yate.

Xanthidium Brebissonii, (Ralfs)
Ashley Down ; Horfield.

Xanthidium fasciculatum, (Ehr.)
Ashley Down ; Dundry ; Yate.

Xanthidium octocorne, (Ehr.)
Kingsweston.

Notes on the Physical Geography and Botany of Chili.

BY E. C. REED.

Read at the General Meeting, November 6th, 1873.

Although I have now resided four years in Chili without forwarding you any notes of its natural history, yet I can most honestly assure you that it has not been from lack of inclination to do so. Although I have been for the last nine years a dweller in foreign parts—a wanderer upon the face of the earth—yet I frequently look back with pleasure upon the many evenings that I have spent at the meetings of the Bristol Naturalists' and Microscopical Societies, and I am very happy to see by the "Proceedings" that some good work is done by the members.

New scenes, new Faunas and Floras are joyous things; I have felt and still do feel most keenly the pleasures of contemplating nature in her own domains in parts new to me, but I doubt if these repay one for the home pleasures lost.

Tropical forests offer great attractions to the naturalist, but the unseen, ever present miasmas, will give fevers, and their effects last for years, as I have found to my cost. In addition to these discomforts one does not meet with fellow workers in these regions, and man is a social animal, it must be remembered. I am, almost, the only entomologist resident in Chili, while there are two or three botanists, and I believe that the wish to have fellow workers has induced me to me pay some little attention to the latter branch.

The subject that I now venture to bring before you is the botany of Chili, but first, perhaps, I had better give an idea of the physical geography of this country.

Chili is a long, narrow strip of land, extending from the twenty-fourth degree of south latitude, to Cape Horn; bounded on the West by the Pacific Ocean, and on the east by the summits of the snowy Andes.

The southern and eastern boundary, below the Archipelago of Chonos, is not yet very clearly determined, so I now propose only to consider Chili from the Desert of Atacama to Chonos (lat. 46, S.)

Thus restricted, Chili extends from north to south about 1500 miles, while the width from east to west may be taken as about 130 miles.

Chili derives its mountainous nature from two mountain chains which run nearly parallel from north to south throughout its entire length. The western and lower range is called the Cordilleras of the coast. This range is situated very near the sea, and may have an average height of 1000 feet, but few high peaks are met with ; one of the highest, situated near Valparaiso, called the "Campana de (Bell of) Quillota" rises to about 6130 feet.

This range is much interrupted, as all rivers have to cut through it to reach the sea.

The other range, the "Cordilleras de los Andes," is much higher. Both these ranges are higher to the north, and thence slope towards the south. The Chilian Andes are highest from 32° to 34°. The following figures are taken from the best sources that exist.

Lat. S. 33° 25′	Tupungato	6710 Metres	Considered by some as a volcano, but doubtful
,, 33° 41′	San Jose	6096 ,,	Last eruption 1843. This was rather an earthquake than an eruption.
,, 33° 59′	Vulcan de Maypo	5384 ,,	No record (perhaps in 1871.)
,, 34° 50′	,, ,, Tinguiririca	4478 ,,	Do.
,, 35° 18′	Cerro Colorado	3956 ,,	
,, 36° 00′	Volcan de las Yeguas	3457 ,,	No record.
,, 36° 49′	Chillan	2735 ,,	An eruption from August, 1861, until January, 1865.
,, 37° 2′	,, de Antuco	2753 ,,	In active eruption formerly, ceased in 1861.
,, 39° 12′	,, ,, Villarica	3600 ,,	In 1640 smoke sometimes seen.
,, 43° 10′	Corcobado	2250 ,,	No record.
,, 43° 30′	Yanteles	2020 ,,	

From this list it will be clearly seen that the Andes are much lower in the south than in the north. All our volcanos are situated to the south of Santiago. I have given, above, an account of some of the principal, with notes on their present and past state.

Between these two ranges is a long valley scarcely interrupted by any transverse chain from the city of Santiago (33° 25′ S.) to the Gulf of Ancud (41° 40′ S.) This valley also slopes to the south, as follows:—

33° 4′ S.		709	Metres.
33° 25′ ,,	Santiago	569	,,
34° 10′ ,,	Rancagua	519	,,
34° 35′ ,,	San Fernando	336	,,
35° ,,	Curico	228	,,
36° 40′ ,,	Chillan	160	,,
37° 46′ ,,	Angol	102	,,
41° 40′ ,,	Puerto Montt	0	,,

Below this I consider the Island of Chiloe and the Archipelago of Chonos as representing the coast range, while the central plains are below the sea level.

Of course the Andes are capped with eternal snow, but the snow line is difficult to determine as so many small and strictly local circumstances have to be taken into account. In the latitude of Santiago it is estimated at 11,000 feet, and I have no doubt that this is nearly correct, but with all submission to the bookmakers, I have several times been as high as from 13,000 to 15,000 feet, and have never known precisely where to draw the line.

Soon after my arrival in Chili I crossed the Andes, in order to observe the limits of snow, plants, &c. Then I found that all my previous ideas formed from books were very unlike the reality. On reaching the height of 11,184 feet, I saw a large field of snow some 800 feet above me, and I expected that I should have to travel on this until arriving at about the same altitude on the eastern slopes, but I was soon undeceived; after passing this snow, which was so extensive that it gave rise to a brook, I travelled again on snowless land, and actually gathered some of the violets and the *Caloptilium largasecæ* now before you from 500 to 1000 feet higher up. And until I reached the summit of the pass, 13,475 feet, I found the road—if I may use this term—clear of snow except in a few hollows, although every part above, and large fields at least 4000 feet below me, were covered with it.

The wind is very strong in the day-time on the mountain tops, so strong that it is considered prudent to cross early in the morning, as towards midday it is sometimes almost strong enough to blow over man and horse. I cannot positively affirm that such a thing has ever occurred, but I think it a very possible event.

Once I was crossing the side of a ridge of frozen ground, so steep that one false step would rolled me down some thousand feet into a torrent of ice-water below; I was on horseback, and so benumbed with cold that I could not venture across on foot; when a sudden gust of wind actually stopped my horse, and blew my *poncho* over my head so as completely to blindfold me. The only thing I could do, was to remain motionless and blindfolded until the gust had passed. This might have been half a minute but it appeared to me about an hour, during which time my horse, evidently understanding our danger, stood trembling in in every limb. This incident will give some idea of the force of the wind in these high places, and its importance with regard to the perpetual snow-line. The slope of the ground must also be taken into consideration.

Probably the heat of the sun is the principal cause of the retention of snow on the mountains, for when the snow has been well ground into small fragments by the wind the top is slightly thawed by the sun, and the water so formed trickles into the interstices, and freezing forms a solid mass. I do not know any English name for the mass so formed. The French call it "*nevé*."

As may easily be imagined, the cold dry air descending from the Andes greatly modifies the climate of the central plains.

Then the coast is washed by a cold stream from the Antarctic Ocean, Humboldt's current, which greatly reduces the temperature on the coast, so that our climate is not as warm as its geographical position would seem to give it.

The height of the Andes also affects the rainfall, by breaking the force of the east winds, and depriving them of a large amount of moisture. The following table will give an idea of the temperature and annual rainfall :—

		Tem. aver. of year.	Summer.	Winter.	Annual Rainfall.
	Coquimbo .	. .	. .	. .	7 In.
27° 20 ′S.	Copiapo .	58° Fah	65°	53°	?
	Valparaiso.	57° ,,	61°	51°	?
33° 25′	Santiago .	55° ,,	65°	45°	16½ ,,
	*Talca . .	60° ,,	72°	48°	22 ,,
36° 45′	Conception.	?	?	?	54½ ,,
39° 47′	Valdivia .	52° ,,	61°	41°	114 ,,
41° 28′	Port Montt	53° ,,	60°	55°	107 ,,

This distribution of rain is, I believe in direct contradiction to general laws. Roughly speaking, we may say that in the Desert of Atacama it never rains, while in Chiloe dry days are scarce. I once made a six weeks' voyage to the Chonos Archipelago, and during this time I had *not one* fine day. It rained but slightly on four or five days, all the rest of the time in torrents, and this in the summer months.

With regard to the desert of Atacama, I regret to say that we have no RELIABLE knowledge of its rainfall. Professor Philippi made a journey to the desert in 1843-4, and after due enquiry came to the conclusion that it rains there about twice in a century. My friend, Capt. Vidal, of the Chilian Navy, is of opinion that it rains there every few years. This certainly is somewhat vague but I can obtain no better information.

Santiago is situated nearly in the centre of Chili. Here it rarely rains from the middle of September to the end of April. The natives pride themselves on their fine summers; but for my part I should enjoy a few smart showers occasionally, for in consequence of these long droughts, the roads are covered with from six to eight inches of the finest and most annoying dust, rendering a walk or ride in the country truly painful. Trees, houses, people, all are covered with this powder constantly. Luckily the wind is very seldom strong here, or Santiago would be unbearable. The poor naturalist finds his occupation, so far as collecting is concerned, gone during the summer unless he makes a journey to the rainy south.

If it were not for the irrigation of the land, no crops would grow here; but through that means the land here produces excellent crops. About two leagues to the north-east of the city commences a large track of land unprovided with streams, and which, when I last saw it, was stocked with about one starving cow per square mile; but this is a strong contrast with all other parts of the district. The only plant that resists the drought here is the *Acacia cavenia*, about one stunted bush per acre being visible towards autumn. After the winter rains everything is green—even the dry stony cordilleras of the coast are covered with innumerable flowers—so that a journey by railroad from Santiago to Valparaiso is delightful. A little hill near this city bears from 400 to 600 species of flowering plants in the spring,—but the spring once passed, the only resort away from dry specimens, dusty roads, and drier if not dustier books, is to be found in some of the mountain valleys situated about a day's ride, or say 50 miles, from the city. There, under the shade of a Quillay, (*Quillaja saponaria*) or Maiten, (*Maytenus chilensis*) one can camp out and botanize, insectize, or moralise, profitably; and, thanks to the numerous holidays observed in these countries, frequently.

These two trees are nearly the only indigenous species of any size in the Andes in this province. The Quillaja is decreasing rapidly, as its bark is in great demand for washing wool, &c. No indigenous tree grows in the plains here or to the north, but the hills a little to the south have some fine patches of forest.

Soon after my arrival here I was astonished and delighted to find nearly a square mile of Robles (*Fagus* sp. ?) within some 70 miles of Santiago, high up on a crest of the coast range. Why that patch of forest exists I cannot explain. All around was baked hard and dry as a rock by the sun. Away from the shade of the trees no plants except a few bulbous and tuberous species were to be found. Insects in the form of hard-shelled Heteromerous Coleoptera or a few Carabici only were to be seen, but in the shade I found many interesting things. Water there was so scarce that the men had to dam the stream to procure water for ourselves and horses.

More to the south, fine forests gradually appear, and in the provinces of Concepcion, Aranco, and Valdivia, a great part of the land is covered with dense forests of *Myrtus*, *Fagus*, *Pinus*, *Eucryphia*, *Drymis*, *Escallonia*, *Edwardsia*, *Aristotela*, *Flotovia*, and many others. The Flotovia, a genus of Compositæ, is the largest Chilian tree, and frequently grows to an immense size.

Still, even in Valdivia, the "central plains" can boast but few trees, these being replaced by bushes, amongst which several species of *Berberis* are conspicuous, and low plants. As I found in Brazil, travelling from the sea inland, heavier forest, thinner deciduous forest and pampas, so I find here forest, thick bush, and pampas, but nearly all the Chilian trees and shrubs are evergreen: No ephiphytal Orchids or gigantic Ariods occur here, and the *Bromelias* are few in number, but a species of *Cissus* winds from tree to tree, and fine species of *Chusquea* replace the tropical bamboos.

I had hoped to have given some definite ideas of the principal "centres of vegetation" in Chili, but I find I am not yet in circumstances to do so. There are so many graduations of climate, altitude, &c. to be considered, that I now intend to obtain exact information on the occurrence of each indigenous species before I publish much on that point; but I have no hesitation in pointing to Valdivia as the most abundant centre, and Magellan as another. Going from Valdivia to the island of Chiloe, we find the climate slightly colder and a little more rain falls. The island is one great forest, except near the few towns and villages where the scanty population have cleared some ground to plant potatoes. Except a very few stragglers from Magellan, all the native plants are also found in Valdivia, but on the other hand the number of species found in Chiloe is much smaller than in Valdivia.

Proceeding still farther southward to Chonos, the Valdivian species become fewer and fewer, and nearly all the new forms met with are stragglers from Magellan.

In these remarks, however, I do not include the vegetation of the Andes. The studies that I have made on our mountain flowers have as yet given me no clue to their laws of distribution. For example, the little *Colobanthus quitensis*, Bartl. was first found at Quito, under the equator. I have found it in the Andes near Santiago, and in Chiloe, and I firmly believe it occurs also at Magellan. Should this however prove to be a cosmopolitan species, one of my difficulties will be removed.

Last year I found some half-dozen species of plants that had previously been described from Terra del Fuego, growing in a marsh on the coast range in Valdivia, some 2000 or 2500 feet above the sea level. These and similar facts can be satisfactorily accounted for, but cosmopolitan plants are terrible things theoretically. Tho first time I crossed the Andes, I of course noted and collected the plants that I met high up, most carefully—imagine then my surprise and annoyance when, at one of the highest points over 13,000 feet, I found a specimen of the "shepherd's purse," *(Capsella bursa pastoris.)*

I suppose the Capsella is realy a cosmopolitan plant, It occurs all over the country, but at the same time a great many European plants get accidentally introduced.

For example, two years ago I found two or three specimens of the common "groundsel" *(Senecio vulgaris)* in Chiloe; this was, I believe, the first time it had been noticed in Chili; now, it is common in the streets of Santiago, commonest near a nursery garden, so that it must have been accidently introduced with some plants or seeds. I also found a daisy *(Bellis perennis)* in a field in Chiloe, but I have never since seen it in Chili.

To the north of Valdivia the vegetation is very abundant in the provinces of Aranco and Concepcion, and woods are met with even more to the north. A large number of plants are met with in Concepcion, some of which occur, though rarely, at Santiago, a much larger number being met with at Valparaiso.

Near the desert of Atacama we get a peculiar Flora; Professor Phillipi obtained 417 species of vascular plants during his journey there. Of these few genera are peculiar, but a large number of the species are of peculiar stunted growth, frequently with large flowers, and somewhat resinous; a peculiarity possessed in still higher degree by large numbers of species from the high Andes.

I annex a list of the families of plants that have been met with in Chili to the end of last year, with the number of genera and species of each. Considering the small numbers of collectors, I consider the number of species enormous, and I have been much surprised to find the Flora of valleys scarcely a mile apart, with equal altitude, rainfall, climate, &c., very distinct.

Amongst a few other plants, I send you a few species of *Colletia* (Rhamnaceæ) directing your attention to *C. nana*, a little resinous species growing in the highest parts of the Andes, and then to the other species growing on the plains. The violets sent also are curious.

I must apologise for the hasty and incomplete manner in which I have written these few notes. I lead by no means an idle life; I am now occupied in finishing a catalogue of the insects of the country—this with my duties in the museum, and my natural history classes, leaves me very little leisure.

		Genera	Species
1.	Ranunculaceæ ...	5	41
2.	Magnoliaceæ... ...	2	4
3.	Lardizabalaceæ ...	2	2
4.	Berberidaceæ... ...	1	28
5.	Papaveraceæ... ...	1	3
6.	Cruciferæ	19	132
7.	Capperidaceæ... ...	1	1
8.	Fumariaceæ	1	2
9.	Bixaceæ...	1	9
10.	Cistaceæ...	1	2
11.	Violaceæ	1	31
12.	Droseraceæ	1	1
13.	Polygalaceæ	3	13
14.	Frankeniaceæ ...	1	8
15.	Caryophyllaceæ ...	8	52
16.	Elatinaceæ	1	1
17.	Malvaceæ	8	61
18.	Tiliaceæ...	3	3
19.	Encryphiaceæ ...	1	2
20.	Hypericaceæ... ...	1	3
21.	Malpigiaceæ... ...	2	7
22.	Sapindaceæ	3	3
23.	Ampelideæ	1	3
24.	Geraniaceæ	2	14
25.	Vivianiaceæ	3	15
26.	Tropæolaceæ... ...	1	8
27.	Oxalidaceæ	1	57
28.	Linaceæ...	1	6
29,	Zygophyllace ...	5	6
30.	Xanthoxylaceæ ...	2	2

		Genera	Species			Genera	Species
31.	Rutaceæ	1	1	71.	Primulaceæ	9	15
32.	Corixiæ	1	1	72.	Sapotaceæ	1	2
33.	Celastraceæ	2	5	73.	Jasminaceæ	1	1
34.	Ilicineæ	1	2	74.	Apocynaceæ	2	2
35.	Rhamuaceæ	6	25	75.	Asclepiadaceæ	8	22
36.	Anacardiaceæ	2	7	76.	Gentianaceæ	4	17
37.	Leguminosæ	26	269	77.	Bignoniaceæ	5	23
38.	Rosaceæ	10	44	78.	Polemoniaceæ	3	12
39.	Onagraceæ	9	38	79.	Convolvulaceæ	7	26
40.	Haloragaceæ	6	16	80.	Hydroleaceæ	1	1
42.	Lythraceæ	2	8	81.	Hydrophyllaceæ	2	8
42.	Myrtaceæ	3	44	82.	Boraginaceæ	11	70
43.	Cucurbitaceæ	1	1	83.	Labiatæ	16	39
44.	Papayaceæ	1	1	84.	Verbenaceæ	5	46
45.	Passifloraceæ	1	1	85.	Acanthaceæ	2	2
46.	Malesherbiaceæ	1	10	86.	Orobanchaceæ	1	1
47.	Loasaceæ	8	44	87.	Solanaceæ	21	96
48.	Portulaceæ	9	86	88.	Nolanaceæ	6	31
49.	Paronychiaceæ	5	11	89.	Scrophulariaceæ	21	138
50.	Crassulaceæ	1	10	90.	Plumbaginaceæ	4	7
51.	Mesembryanthaceæ	1	1	91.	Plantaginaceæ	1	24
52.	Cactaceæ	4	27	92.	Nyctaginaceæ	2	8
53.	Grossulariaceæ	1	20	93.	Amaranthaceæ	3	7
54.	Saxifragaceæ	9	44	94.	Chenopodiaceæ	6	29
55.	Umbelliferæ	30	110	95.	Phytolaccaceæ	3	8
56.	Araliaceæ	1	3	96.	Polygonaceæ	6	35
57.	Francoaceæ	2	5	97.	Laurineaceæ	5	11
58.	Loranthaceæ	4	22	98.	Proteaceæ	3	7
59.	Cornaceæ	1	4	99.	Thymeliaceæ	1	3
60.	Rubiaceæ	8	46	100.	Santalaceæ	3	23
61.	Valerianaceæ	3	56	101.	Aristolochiaceæ	1	2
62.	Calyceraceæ	5	28	102.	Rafflesiaceæ	1	1
63.	Asteraceæ (Compositæ)	122	736	103.	Euphorbiaceæ	8	26
64.	Stylidiaceæ	1	1	104.	Empetraceæ	1	2
65.	Lobeliaceæ	5	20	105.	Monimiaceæ	2	3
66.	Companulaceæ	2	4	106.	Utricaceæ	5	16
67.	Gesneriaceæ	3	3	107.	Piperaceæ	1	5
68.	Ericaceæ	3	27	108.	Salicaceæ	1	1
69.	Epacridaceæ	1	1	109.	Cupuliferæ	1	12
70.	Lentibulariaceæ	2	4	110.	Gnetaceæ	1	2

		Genera	Species
111.	Taxaceæ	3	4
112.	Cupressineæ	3	4
113.	Abietineæ	1	1
114.	Hydrocharidaceæ	1	1
115.	Alismaceæ	1	2
116.	Juncaginaceæ	2	8
117.	Lemnaceæ	1	4
118.	Naiadaceæ	2	6
119.	Arachnitaceæ	1	1
120.	Orchidaceæ	6	82
121.	Bromeliaceæ	6	19
122.	Iridaceæ	7	47
123.	Smilaceæ	4	5
124.	Dioscoreaceæ	1	26
125.	Amaryllidaceæ	10	71
126.	Gilliesiaceæ	4	7
127.	Liliaceæ	12	34
128.	Asteliaceæ	1	2
129.	Juncaceæ	3	33
130.	Restiaceæ	1	1
131.	Centrolepidaceæ	1	1
132.	Palmaceæ	2	2
133.	Typhaceæ	1	1
134.	Cyperaceæ	11	111
135.	Graminaceæ	58	331
136.	Equisetaceæ	1	3
137.	Filices	28	108
138.	Lycopodiaceæ	1	6
139.	Salviniaceæ	1	1
140.	Marsileaceæ	1	1
		747	4015

Geology of the Bristol Coal-field.

PART 1.—PHYSICAL CHARACTER.

BY W. W. STODDART, F.C.S., F.G.S.

Read at the General Meeting, December 4th, 1873.

The study of Geology is in many respects one of the most intensely interesting of all the branches of natural science. The hills and vallies, the rocks and woods—so varied in their nature, outlines and beauty—excite in almost every mind some wish to find out their origin. The strange forms that are displayed on the side of the rock, or among the stones of the ploughed field, arrest the attention, and lead to the suggestion that they are the remains of corals and shells. Our wonderful cliffs are crowded with the valves and spiral shells of marine mollusca, or the elegant markings of fishes' teeth.

In many places immense numbers of vertebræ and bones prove by their structure and form that huge saurians once lived and died on those very spots at some remote period. A still closer examination reveals the astonishing fact, that although so similar in form to recent shells, yet they contain no gelatine or any trace of animal substance: all is entirely mineral. That these animals died and became entombed in or near the places in which they are found is evident from their numbers, natural position, and growth. Generation after generation, in all stages of size and age, from the youngest to the adult, may often be noticed in juxtaposition. Sometimes the remains of the last meal swallowed by the animal are found, the digestion of which was suddenly stopped by the rude hand of death. We have many beautiful examples in our Museum. So abruptly must the existence of these family groups have been terminated by some change of season, or violent storm, or change of level, that one can hardly help fancying that some of the old mythological fables that were taught us in our school-boy days must here have taken place, and that the wand of some necromancer had suddenly changed an animated world into stone. Stranger still does it seem when we meet with the relics of tropical animals, such as the lion, rhinoceros, tiger, and sloth; or the fronds of plants that we now only know as living in warm countries. What has become of the red deer whose antlers we find associated with the bones of the wolf that probably hunted them down? Did Bristol ever rejoice in the warmth that now animates the New Zealander or Papuan? Did the shells and fishes that we now pick up at Dundry, seven hundred feet above the sea level, once find a home in the ocean? Can all these seeming improbabilities be explained? It is the object of the present paper to attempt, at any rate, to do so, and to describe the changes that have taken place which have culminated in our own beautiful and picturesque neighbourhood.

Thanks to our canals and railways, and the patient and practical labours of such men as Smith, Lyell, Murchison, Phillips, and many others, the knowledge of what has occurred in the former history of our planet has been greatly advanced. Probably the most useful geological finger-post was that erected by William Smith, when residing in our immediate neighbourhood. While superintending the excavation for the Midford

Canal, Mr. Smith noticed the fact that the beds through which the excavation passed were placed in regular sequence, and each possessed its own specific suite of fossils. This fundamental discovery was the keystone of future observations, and after many repetitions in other places, gave rise to the well-known law,—"*That the order of succession of particular strata, with their particular groups of organic remains, was never inverted; and that they might be identified at very distant localities by their characteristic fossils.*" From that day to this the fanciful theories of older geologists have been discarded for the present stratigraphical doctrine, and the steady progress in what we believe to be the right direction.

The whole of the British Isles have been gradually deposited on the eastern slopes of several submarine volcanic rocks, that many ages since protruded into the waters of an ancient ocean that very probably covered the greatest part of the surface of our globe. From the continued action of the waves the deposits on the western side were washed away, while those on the eastern side not being so much exposed to their destructive energy, were more persistent. By successive depositions therefore *towards the east* was formed that land now so replete, both inside and out, with those sources of wealth that have made our island so famous in the history of the world.

In order to proceed with system and to avoid confusion, our description will be restricted to that part of the country comprised in our President's accurate and very excellent Map of the "Bristol Coal-field." It will be found that no other district of similar extent affords so great a facility for obtaining a good knowledge of geology. It extends from Berkeley to Wells, north and south, and westward from Nunney to Huntspill, an area of about seven hundred and twenty square miles. That any member of the society, or visitor to our neighbourhood, may go and study for himself, a complete list of localities and fossils will be given with illustrative sections.

The following table of the great divisions of strata that will come before our notice, will shew the great range of formations at our disposal. A more delightful and instructive mode of enjoying an occasional holiday can hardly be conceived. The localities given are only a very few of the most typical.

Geological Division of Strata.			Typical Localities.
Post Tertiary.	*Recent.*	Alluvium	Bristol, Shirehampton
		Peat	Cheddar, Glastonbury
	Postplioc.	Gravel	Cheddar railway, Keynsham Saltford
Tertiary			Absent
Cretaceous		Greensand	Postlebury
Jurassic.	*Uppper Oolite*		Absent
	Middle Oolite.	Coral Rag	Not well shewn
		Oxford Clay	Cloford
	Lower Oolite.	Combrash	Do., Marston Bigot
		Finest Marble	Chickwell, Faulkland
		Bradford Clay	Bradford
		Bath Oolite	Coombedown, Lansdn., &c.
		Fuller's Earth	North Stoke, Lansdown, &c.
		Inferior Oolite	Dundry, Cotteswolds
	Upper Lias.	Sands	Dursley, Bath, Dundry
		Clays	Do. do. do.
	Mid. Lias	Marlstone	Do. Dund. Sodbry. Upton
	Low. Lias	4 Ammonite Zones	Horfield, Pill, Keynsham Whitchurch
Triassic.	*Upper Trias.*	Rhœtic	Aust, Almondsbury, Vallis
		Keuper	New River, Cotham
		Dolomite conglomerate	Bristol, Portishd., Clevedon
Permian			Absent
Carboniferous.	*Upper.*	Coal Measures	Mangotsfield, Radstock, &c.
		Millstone Grit	Brandon hill, Fishponds, &c.
		Upper Shales	Clifton, Ashton, do.
	Lower,	Mountain Limestone	Do. Mendips, Tortworth
		Lower Shales	Do. Clevedon, &c.
Devonian		Sandstones	Do. Portishd. Mendps. &c.
		Conglomerates	Do. do. do.
Upper Silurian		Ludlow	Tortworth, Berkeley
		Wenlock	Tortworth, Falfield
		Upper Llandovery	Tortworth, Damory
Igneous Rocks		Greenstone	Damory, Charfield, Woodfd.
		Basalt	Uphill, Mendips, Weston

The total thickness of these strata is no less than about sixteen thousand feet. Of course in no one locality can we uninterrupted see this immense mass; but thanks to Mr. Smith's law, we can trace a tolerably perfect series of the principal formations from the Upper Silurian to the Greensand portion of the Cretaceous period.

An extensive natural section of nearly all, is one well known to most of us, viz., that exposed by the Great Western Railway from Bristol to Paddington. This grand panoramic view of more than one hundred and twenty miles in length, exposes in regular sequence most of the formations with which we have to do. On leaving London the railway passes over the flat surface of London clay, with its brick-fields here and there shewing a section of drift gravel, until it reaches the undulating chalk hills of Berkshire. There is abundant evidence of this portion of England having been subjected to the denuding influence of an open sea. The next few miles extend over the flat and damp beds of the Oxford clay. On arriving at Corsham, however, the character of the land surface is seen to have undergone a complete and thorough change. The railway embankment reveals the rocky beds of the Oolite, which mount higher and higher until the shrill whistle of the engine announces that the train is passing through Boxhill. On emerging from the tunnel the beautiful scenery surrounding the city of Bath bursts into view. The railway next passes over the regular beds of the Lias for ten or a dozen miles, when another change takes place, and we are carried through portions of the Lias and the Coal Measures, till we are landed at the Great Western terminus on an extensive flat of alluvial mud. A cab ride to Clifton finishes our journey, the slowness of which tells the passenger that he is toiling up the slopes of the Carboniferous beds which, by an ancient disturbance of the earth's surface, have been uplifted to more than three hundred feet above the level of the sea. We thus perceive that our journey has taken us over most of the strata marked on the Map of our President which we have taken as our guide.

A close observation of our district will shew that the portion of country on the east is a series of heights having an altitude of six or seven hundred feet; while the western part is a continuation of low, flat country not many feet above the mean sea level, the flatness only being broken by isolated hills that have withstood the action of the waves which in former days washed away and denuded the surface. Across the lower part of the map is seen a ridge of hills very different from those already mentioned, and much higher. As we shall notice further on, these were raised by the violence of volcanic action from underneath.

The watershed of the country of the Bristol Coal-field is drained by several rivers running westerly into the Bristol Channel. The Avon receiving in its course the Frome and Trym, divides Gloucestershire from Somersetshire. The most southerly high lands are drained by the Axe, that rises near Wells, and is joined by the tributary that emerges in so singular a manner from the Cheddar rocks, after passing under-ground for a considerable distance.

The western sea-bord is so low that in many places it is below the spring-tides which would periodically flow over its surface if the inhabitants did not keep in good repair strong sea banks many miles in extent. Sometimes a stone wall ten feet high has been required for the same purpose. From these low levels the hills rise abruptly till they reach a considerable elevation.

The following is a list of the altitudes of a few:—

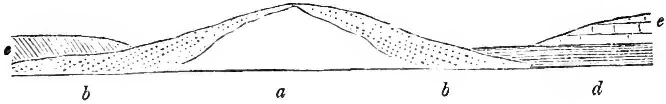
	Feet.
Dunkry Beacon	1668
Will's Neck, nr. Bagborough	1270
Blagdon Hill	1092
Bishop's Lydiard...	1060
Shepton Mallett Beacon ...	1050
Penhill, near Wells	940
Ninebarrow Hill	900
Charterhouse	840
Lansdown	813
Stinchcombe Hill	704
Dundry Hill	700
Bathford Hill	675
Nibley Hill	660
Maes Knoll	639
Tyndal's Monument	630
Brent Knoll	617
Broadfield Down...	611
Cheddar Cliffs	526
Bleadon Hill	447
Upton Cheney	436
Worle Hill	350
Wotton-under-Edge	332
Durdham Down	319
Clifton Down	315
Blaize Castle	300
Ashton Hill	270
Brandon Hill	250
Ashley Down	210
Kingsdown	187

The climate of the district varies very considerably on account of the great difference in soil, the variety of elevation, and the shelter given from the winds passing through the vallies by the hill sides. Difficulty of drainage is also a potent cause of climatic difference, and has a most powerful influence on the health of the inhabitants, much more so than people generally think.

The whole of the district drawn on the Map is Palæozoic, bearing patches of Secondary deposits on its surface. No stratification has been largely disturbed by volcanic forces that have been exerted at different periods. The last evidently produced an anticlinal, running irregularly from N. E. to S. W., and in its course giving rise to faults at nearly right angles. Sometimes the eruptive lava passed through and appeared on the surface of the ground; and sometimes only rose far enough to cause an elevated disturbance. Before commencing a description of the several geological formations, we had better stay and consider these disturbing influences by an examination of the igneous mass itself.

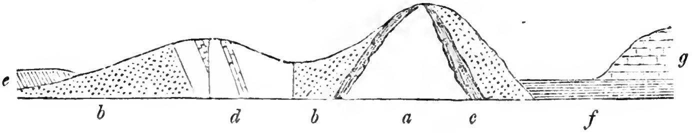
These eruptive rocks have had the general names of Trap and Greenstone. We soon find from lithological scrutiny and chemical analysis, that they are composed really of many distinct mineral substances. We must always remember that these igneous rocks were not ejected by an aerial volcano, as Etna or Vesuvius, but were actually molten masses from the interior of the earth, and protruded through the bed of the sea, and always *under water*. For this reason these igneous rocks have characters that differ from the lavas of aerial craters on account of the great pressure under which they were ejected. As the molton matter burst through, the beds themselves were half melted and changed. If through beds of sand, for instance, we often see a gradual sequence from loose sand to a completely solid rock of quartz. The best localities for observation are the Tortworth district, at Woodford, or Damory Bridge, at Charfield, Avening, Broad-field Down, Weston-super-Mare, and Uphill. The oldest of these rocks are those of the Tortworth district, and were ejected at a very early period of the earth's history,—after the Silurian, and before the Carboniferous era had fairly commenced. This is plainly shewn in the following sections at Horsley quarry and Damory Bridge, especially the latter place. Of course these sections are only diagrammatic, and not drawn to scale.

Fig 1.



a Igneous rock. *b* Upper Llandovery Sandstone. *c* Devonian. *d* Trias. *e* Lias.

Fig. 2.



a Igneous rock. *b* Upper Llandovery Sandstone *c* Altered Llandovery. *d* Upper Silurian. *e* Devonian. *f* Trias *g* Lias.

The beds of the Upper Llandovery, through which the Greenstone passed, were lifted up and partially altered. In the parts nearest the surface, which allowed the steam and gases to escape, the rock still shows the impressions of the bubbles and is vesicular in its character, and where they were large and afterwards filled with earthy matter, forms the kind of stone termed by mineralogists, Amygdaloid. At the quarry near Damory Bridge, the sands may be traced from loose strata containing the usual fossils through several transition stages, as semi-molten sand to those parts actually in contact with the hot lava when transparent and solid quartz rock became the product.

A still more remarkable proof of this fact may be studied in a field near Charfield railway station, where lifted up *on the top* of the Trap, and also *embedded in it*, are fossils themselves unaltered in form.

The central part of the Greenstone is solid, and formed of Felspar and Hornblende principally, but towards the surface interspersed with veins of Calcite and Quartz. Unfortunately, the several constituents are so intimately blended together, that no separate crystals can be obtained for crystallographic measurement or analysis. In some places the rock resembles Serpentine or Steatite. In others may be found nodules of Chlorite, Prehnite, and Gerlite. Indeed, this is one of the best English localities for Prehnite, and the locality is named in our works on Mineralogy.

The following are three analyses that have been made of the rocks in this quarry. The first sample was taken in as pure a state as possible from the centre of the quarry. It did not effervesce with an acid. The second was taken when the mass was mixed with inseparable particles of Quartz; and the third where particles of Calcite occurred.

	1	2	3
Silica	57·52 ...	67·34 ...	43·66
Alumina	16·52 ...	12·34 ...	12·34
Potassic Oxide ...	10 34 ...	7·97 ...	7·98
Sodic Oxide	·72 ...	·31 ...	·30
Calcic Oxide	4·60 ...	3·61 ...	28·10
Magnesic Oxide ...	5·14 ...	3·86 ...	3·86
Ferric Oxide	3·01 ...	2·26 ...	1·98
Loss	2·15 ...	2·31 ...	1·78
	100 00 ...	100 00 ...	100·00

The altered Llandovery beds before mentioned were next examined, and had a purplish color from iron contained in the original sand. They are more conveniently placed for examination on the western slope of the Greenstone. Their vesicular and amygdaloidal character may be easily seen. Their appearance and chemical composition are very similar to the Trap seen near the Charfield Station, both in the quarry near the roadside and on the banks of the Midland Railway.

In this quarry may be seen some pieces containing numerous small specks of Lime, and probably formed from Limestone calcined at the time of eruption. The following analyses of the original Llandovery Sandstone and the Charfield section appear to prove that the latter is not all true Greenstone, but formed from *strata altered* by close contact with highly heated lava. No. 1 is analysis of the original Llandovery Sandstone, while Nos. 2 and 3 are of two distinct places in the same Charfield quarry.

	1	2	3
Silica	90·07	82·45	89·45
Alumina	2·13	3·31	2·53
Magnesic Oxide	·24	·23	·21
Calcic Oxide	1·62	——	——
Ferric Oxide	5·53	13·06	7·42
Loss	·41	·95	·39
	100·00	10·000	100·00

In the Llandovery Sandstone are scales of Mica, which are also to be detected in the Charfield quarry and on the sides of the Damory Greenstone.

Augite could not be found, as probably may have been expected, for that substance is not very generally perceived with the Quartz rocks. Perhaps this idea of altered Sandstone gave rise to Sir R. Murchison's name of "Volcanic Grit," which is an appropriate one.

Mr. Aikin alludes to these beds as Micaceous Sandstone dipping away from the Trap at a high angle. (Geol. Trans. Vol. 1, old series, 212.)

The igneous rocks of Broadfield Down, Uphill, and Weston-super-Mare are of much later age, and have a totally distinct appearance and composition. They are basaltic in their character, and ferruginous, earthy, and a deep reddish brown. In some places the ferric oxide is so abundant as to form crystalline concretions. The following are two analyses—No. 1, of the Trap at Weston-super-Mare; Nos. 2 and 3 of that from Broadfield Down. The last is an analysis made by the late Mr. Herapath, and given by Charles Moore, Esq., F.G.S.

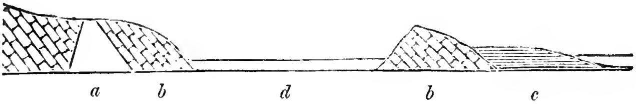
	1 Weston.	2 Broadfield.	3 Broadfield. (Herapath.)
Silica	53·10	50·34	51·00
Alumina	12·81	97·6	15·30
Potassic Oxide	1·63	2·01	——
Sodic Oxide	2·98	3.04	——
Calcic Oxide	9·91	10·33	10·00
Magnesic Oxide	6·43	5·62	6·10
Ferric Oxide	11·54	16·11	12·60
Manganesic Oxide	1·32	2·13	——
Loss	·28	·66	5·00
	100·00	100·00	100·00

These igneous rocks appear to have been forced through the submarine strata at the close of the Rhœtic or the end of the Triassic period. The former is the most probable, from the physical conformation of the strata as now seen. At Uphill the Rhœtic beds are in actual contact with the Trap, and are completely turned over; and as the other beds a short distance off are not disturbed, it is evident that they must have been in a soft state when the eruption occurred. It was this upheaval that formed the Clifton chasm, and the Cheddar Valley, with its cliffs and caves.

Mr. C. Moore, who has been working in this district for so many years, has discovered at the top of the Mendip range, the Trap itself, having still the same basaltic character. He has settled therefore the question of how these great ranges of hilly country and the numerous faults were produced.

The following section shows the fracture of the Carboniferous Limestone near Weston-super-Mare.

FIG 3.



a Igneous rock. *b* Carboniferous Limestone. *c* Lias. *d* Alluvium.

Thus were formed the well-known and lovely scenes in our neighbourhood. We have only to call to mind Clifton, Cheddar, Tintern, Chepstow, and Tortworth, to realize the beauty that has arisen from one of the most awful phenomena of nature.

The minerals found in the district are important and numerous. The mineralogist may collect a great variety of good specimens of iron, lead, zinc, barium, and strontium, with their secondary forms, but these had better be described when speaking of the beds and strata in which they occur.

Reports of Meetings.

GENERAL.

The first Meeting of the Society in 1873, was held at the Bristol Museum and Library, on the evening of January 2nd. Mr. Stoddart gave a Lecture on the Natural History of Spiders, which was illustrated with diagrams. After showing the distinction that clearly existed between Spiders and true insects, the Author explained the minute anatomy of the Araneida, and exhibited a large number of microscopic dissections. The list of Bristol specimens will appear in a future communication, when future observations shall have made it more complete, especially as many species usually considered as rare in Britain occur plentifully in the immediate neighbourhood; as, for instance, *Segestria perfida*, which is frequently met with.

The next Meeting was on the evening of March 6th, 1873. Dr. Beddoe, F.R.S., delivered a Lecture on "Ethnic Migrations." A short report of this, as taken down by the Hon. Secretary, appears above.

The next Meeting was on Thursday evening, April 3rd, 1873. Mr. Tawney read a paper on the "Coal Question." It has appeared above.

The Annual Meeting was held Thursday evening, May 11th. The Report of the Council was read and adopted; the accounts were passed, and officers elected for the ensuing year. This Report has already been printed and distributed.

The next evening Meeting of the Society was held on October 2nd, 1873. Mr. S. H. Swayne, M.R.C.S., gave a Lecture on "Recent additions to the Zoological Department of the Museum." This was followed by a paper by Mr. S. Smith, M.R.C.S.E., "On the occurrence of Filaria Gracilis in the Great Omentum of a Spider Monkey." These appear above.

The next Meeting was held on Thursday evening, November 6th, 1873. Mr. E. C. Reed (of the National Museum, Santiago, Chili) read a paper on "The Physical Geography and Botany of Chili." This has appeared above. In the discussion afterwards, Dr. T. Inman made some remarks on the causes of fever in warm climates. Whether there was such a thing as malaria he seemed to doubt, and referred all such fevers to the subject having taken a chill. Some remarkable facts of sleeping with impunity in most malarious places were cited, the precaution having been taken to be well covered.

Mr. Stoddart then communicated a list, with localities, of Desmidieæ found in the neighbourhood of Bristol. This is printed in full. The Hon. Secretary made some remarks on the best way of mounting these organisms: instead of preservative fluids he advised simply to let them dry on the slide under a thin cover and keep them so. For examination, on taking them from the cabinet simply moisten with water. He held, that treated in this way they reassumed their natural colour and form.

The last evening Meeting of the year was held Thursday, December 4th. Mr. W. W. Stoddart, F.G.S., read a paper on the "Physical characters of the Bristol Coal-field." This is the first of a series of papers by him on the Geology of the Bristol district. After the reading of the paper, the President, Mr. W. Sanders, F.C.S., made some remarks on the Trap rocks of the neighbourhood. He did not hold that the Trap of Charfield Green was altered Llandovery Sandstone. He then noticed the occurrence of an interbedded Trap which was seen in making

Wickwar Tunnel many years ago. It has long been bricked up, and may never be seen again. It occurs in the Carboniferous Limestone, and appeared truly interbedded.

Mr. Harding then exhibited some living specimens of *Astynomus ædilis*, both sexes; they were taken near Hartlepool. Some mounted specimens were presented to the Museum.

EXCURSION.

The only general Excursion taken by the Society this summer was on July 2nd. A party of twenty-five left Bristol by an early train for Cheltenham, being joined at Mangotsfield Junction by the Secretary of the Bath Natural History Club, and a few other friends.

The programme of the day was the study of the Inferior Oolite at Leckhampton, under the guidance of Dr. T. Wright, who had kindly put his unrivalled acquaintance with these Jurassic beds at the disposal of his Bristol friends. Dr. Wright met the party at the station, and they all proceeded in carriages straight to the foot of Leckhampton Hill. They were here joined by another party almost equally strong in numbers from Cheltenham, of whom the greater part were ladies, eager to join in the advantages of a field demonstration from the learned Professor, and if we may believe report, already well initiated into the mysteries of rocks and fossils.

After a short toil up the side of the tram-incline, down which the loaded trollies with their freight of building stone were constantly running, the base of the quarry was reached. Dr. Wright here pointed out the chief groups or divisions of the strata, *e,g.*, the freestone beds, and so on, but shortly dismissed the party, in order that they might ply their hammers for awhile, adding that when they assembled again at one o'clock, he would give them a detail lecture on the geology of the district, and leading them round the hill, would point out the several beds, and some of the more important features to be observed.

As far as the find of fossils is concerned, we cannot say that the search in the quarry and waste heaps met with the success expected; everyone was ready to abandon the quest when the piping of the whistle told them that the lecture was about to begin.

Dr. Wright commenced by pointing to the broad vale of the Severn, on the far side of which were seen to advantage the range of the Malverns and May Hills; while on the Leckhampton side extended the long table-land of the Cotteswolds, with its spurs and bays and detached outliers, rising in the Hill above to the height of nine hundred and sevety-eight feet. Now to the geologist there was the greatest difference between these two ranges. The Malverns were the type of "the old life,"—the beings that peopled the world when those deposits were forming were all Palæozoic forms. Moreover, the axis of the Hill was formed of metamorphic rocks, which are some of the oldest in Great Britain, and date from times immeasurably remote. The Cotteswolds, on the other hand, showed no metamorphic or plutonic rocks; they consisted also of beds following each other without any great unconformability, and all the living organisms of that period belonged to the Kainozoic, or new order of beings.

Between these two ranges flowed comparatively recently the sea,—a straight between two old coast lines; in fact the valley of the Severn is often called by geologists "the ancient straits of Malvern."

The physical geography of the Cotteswolds was next briefly and lucidly explained, comprehension being much aided by the fine large diagram and section which Dr. Wright had brought with him, and which was spread open before the party. In a few words, the form of the range, the gentler slopes at the base of the hills, the steeper cliffs above, the projecting spurs, the retreating bays, the detached outliers like Bredon Hill, which was full in the face of the audience, or Churchdown Hill on their left, and Robin Hood behind,—all these features are the product of two elements, viz., on the one hand the nature of the strata, and on the other the action of denuding agents. The base of the Hills and floor of the valley were of L. Lias clays, and limestones; on these rested the harder beds of the Middle Lias and the Oolite rocks; these latter stand out in steeper masses owing to their superior hardness, while the clays are washed away and moulded by rains and tides. It was the patch of Oolite and bluffs of Marlstone of Bredon Hill which were the cause of that hill's existence; these had protected the lower clays against denudation and its consequences.

Turning now to the Inferior Oolite, of which Leckhampton Hill is composed, Dr. Wright explained that the wonderful series of beds, over two hundred feet thick, contained different fossils in different levels, and the labours of palæontologists had shown (of whom we may add Dr. Wright is perhaps the chief) that these had a definite position in relation one to the other. The most characteristic group in the secondary rocks were Ammonites. Here producing three from his bag, Dr. Wright enlarged on the remarkable persistence with which these distinguish different levels or horizons. These were *Amm. Murchisonæ*, which is found in the lower beds of the Inferior Oolite; *A. Humphresianus*, which characterises the beds above; and thirdly, *A. Parkinsoni*, which distinguishes the top beds of the series. These always occur in the same order: their relative position is constant not only in England, but in France, and as far as Suabia, where the lecturer's friend, the late Dr. Oppel, had found it in the same position, and accompanied by the same fossils, as we find with it in England. These Ammonites are therefore of the greatest importance to palæontologists.

Passing then from the objects, uses, and application of

Ammonite-zones and fossil groups, the lecturer proceeded to demonstrate the different beds into which the hill is divided. At the base of the quarry now hidden from view are the "Upper Lias Sands," about two feet thick; this horizon is distinguished by a special set of Ammonites. Above this we have the "Pea-grit," a remarkable bed, about forty feet thick. The company now began to follow their guide's steps, who by taking them around and over the hill led them past the different strata in succession. Dr. Wright related how when he had brought M. Triger, a French geologist, to this spot, and showed him the Pea-grit, the latter went into raptures, and kneeling down worked away till he had obtained several blocks, which are now carefully deposited in the Museum at Metz. It is certainly no easy task to realize how these curious round concretions were formed, for most beautiful and delicate fossil Polyzoa were found growing on them uninjured, though so frail. The next object of interest was the bed of the *Terebratula simplex.* This shell is seen in *sitû* at the base of the freestone beds. As they passed under the detached, turretted rock known as the "Devil's Chimney," it was explained that the fine thick beds of which it was composed, belonged to the freestone group,—a set of beds which furnishes the building stone of the district. It was a lovely afternoon, and the walk round the hill was most charming, the freshness of the air and the brightness of the sun-lit landscape being very exhilarating. Having gradually mounted, the party now had under their feet the bed of "Oolite marl," a bed of clay or rubble, characterized by abundance of *Terebratula fimbria*, and numerous other fossils. This bed has yielded Corals; indeed, the material of the Oolitic hills suggests that these deposits have been formed from the waste of some such reefs as are now to be seen round Australia. If this be so, it forms a proof *per se* of the enormous lapse of time in geology. Above this come the bastard freestones and ragstones which are not good enough for building purposes: they are also unfossiliferous. Doubling back over the top of the hill, the Roman camp was next passed, and what was said to be a problematic barrow. The party soon emerged into the "Gryphite and Trigonia-grit" quarries. These beds are a sort of ragstone, and were used for mending the roads. They contain extremely characteristic fossils, viz., *Gryphea subloba* and *Trigonia costata* respectively. The masses of Gryphea constitute a perfect oyster-bed of Jurassic times.

This completed the tour of the hill and the series of Inferior Oolite strata. The company then descended the hill; a vote of thanks was unanimously passed to Dr. Wright; those who had arrived in carriages stepped into them again and drove to the Plough Hotel, where a well-cooked and ample dinner awaited them. Of course, a very detail vote of thanks was again offered to Dr. Wright, who only said good-bye as the carriages started again for the station.

Botanical Section.

JANUARY 16th, 1873. Annual Meeting. Mr. B. N. Lobb in the chair. The accounts of the present year were audited and passed, and a subscription of one guinea was voted to the Library fund. The President and Honorary Secretary were re-elected, with thanks for their past services.

At the conclusion of the Annual Meeting an Ordinary Meeting was held, at which Mr. Jacques exhibited a collection of plants from Bude, London, and Northamptonshire.

February 20th. The meeting of the Section was held by invitation at the residence of the President, Mr. Leipner, who made an interesting communication on the *Characeæ*, illustrated by a fine collection of specimens.

March 20th. Mr. B. N. Lobb exhibited a collection of specimens from Dartmoor.

June 19th. An excursion to Brockley took place.

August 28th. Under the direction of Mr. Dunn, an excursion was taken to investigate the neighbourhood of Nailsea Moor.

November 20th. Mr. Yabbicom exhibited specimens from West Cornwall. The President, Mr. Leipner, handed in a collection of Chili plants, collected and presented by Mr. E. C. Reed, a former member of the Section, and now of the National Museum in Santiago, Chili.

December 18th. The evening was occupied in mounting specimens for the herbarium.

Entomological Section.

Several outdoor excursions were taken during the summer. The first evening meeting was held at the Museum, on October 14th, 1873, when Mr. E. C. Reed, of the National Museum of Santiago, and formerly Hon. Secretary of the Section, was present, and read a paper on the Entomology of Chili. The following is an abstract of Mr Reed's remarks.

"Chili is far in advance of all other South American nations with regard to all the natural sciences. Many years ago the government of Chili had a work published with descriptions of

Coleoptera	875	species.	Hymenoptera	335	species.
Orthoptera	46	,,	Lepidoptera	110	,,
Neuroptera	32	,,	Diptera	210	,,
Hemiptera	152	,,			
			Total	1760	species.

A present the National Museum alone possesses more than double that number of species in its collections. For example, in the work referred to, only twenty four species of *Buprestidæ* are described, while a monograph of the Chilian members of this group recently published by Mr. Reed, contains descriptions of sixty seven species. The number of Lepidoptera described was also remarkably small, only 110 species; but Mr. Reed remarked that he had brought over several hundred undescribed species, descriptions of which would shortly appear.

Attention was called to the peculiar physical geography of Chili; its insect fauna was remarkable for an European like character with a few Australian forms, while on the other side of the Andes, not more than ninety miles from Santiago, the insect fauna would be quite of a Brazilian type, and the climate almost tropical.

Four species of *Cicindelidæ* occur in Chili, one Agrius and three *Cicindela;* the *Megacephala Chiliensis* of Laporte is really from the Argentine Republic, and has really not been found in Chili. Mr. Reed proposes that it should be called in future *Tetracha Laportei.*

The Carabidæ number about one hundred and eighty species, the genus Carabus fourteen. The Hydrodephaga and water beetles generally are few in number. One species of Necrophorus has recently been discovered in Chili, previously only one species was known in all South America, viz., that found by M. D'Orbigny in the interior of Bolivia.

Lamellicorns are represented by about fifty species. *Heteromera* are common in the dry northern plains and mountains.

Among the *Tetramera* are about one hundred species; there are two hundred and fifty Curculionidæ; numerous *Phytophaga.* The *Trimera* include about twenty-five species. Mr Reed concluded by a few remarks on the other orders, and exhibited a number of new and interesting species from Chili, the island of Juan Fernandez, and the Argentine Republic; also a number of beautiful drawings of Chilian Lepidoptera.

The next evening meeting was held November 11th, 1873.

Mr. E. Wheeler exhibited some specimens of a species of *Phædon,* captured by him in Norway, were they were occurring in countless numbers on alder trees, the trees in some places being quite defoliated by them.

Dr. Smith exhibited a living Coleopterous larva received from Melbourne, feeding in wood, of apparently a species of gum tree (Eucalyptus.)

A large number of beautiful and interesting species were also exhibited by other members of the Section.

The Hon. Secretary then read some notes communicated by a friend in Canada, on some distinctive American beetles, illustrated by specimens; among the species noticed were *Doryphora* 10 *lineata*, Lema 3 lineata, *Macrodactylus subspinosus*, and *Lachnosterna quercina*.

Geological Section.

The first evening meeting of this Section was held January 8th, 1873, at the Bristol Museum and Library.

The accounts of the past year were examined and passed as correct. The President and Secretary were unanimously re-elected.

A paper had been promised by the President, but owing to sudden indisposition he was unable to attend, and the meeting occupied itself with an extemporised discussion on "Evolution" and the influence this theory has had on geological enquiry.

The next evening meeting was held February 12th. There were exhibited some bones of Cave Mammals from Blagdon, which Mr. Sherwood Smith had presented to the Museum. They came from a fissure in the New Red Conglomerate, and from a depth of forty feet; they were found in sinking for iron-ore. The miners unfortunately did not pursue the fissure in a N.W. or S.E. direction, in which case more bones might have been found. As the fissure was apparently closed at the surface it is possible that they just cut the far end or branch of some cavern. There is a small shallow valley about fifty yards to the W. of the sinking, and there may possibly exist there an opening covered up by debris from the ridge above. This small pit was near the top of the Blackdown ridge, above the village of Blagdon, Somersetshire. Owing to its being six miles from a railway those who had been to see it did not hear in time that the sinking was being filled up. It is a cause of regret that the opportunity for making further explorations was thus lost. The bones were a Vestebra of Bos, three molar teeth of Rhinoceros, and distal end of Femur of the same.

Mr. G. Grenfell exhibited a fine specimen of *Nerëites* from the Millstone Grit opposite the Clifton Post Office. From this quarry, where they are getting Hœmatite Iron-ore, he had further obtained *Producta scabricula*, *Streptorhynchus crenistria* and other shells. He presented the Nerëites to the Bristol Museum.

Mr. Stoddart then entertained the Section with an account of "The Geology of Portishead near Bristol." The author stated that this district is extremely complicated on account of faults and irregular grouping from volcanic disturbance. The Devonian beds are extremely interesting as they contain many characteristic remains of fishes. The data of the upheaval that caused these faults was supposed to have been at the commencement of the Liassic period, when the Clifton gorge and Cheddar rocks were placed in their present position. The paper will, however, appear *in extenso* on a future occasion, when describing the Devonian beds of the neighbourhood; and the whole subject will be illustrated by Sections.

The last evening meeting of the Section was on March 12th. The times and places of the summer walks for the Section were fixed. Mr. E. Tawney then read a paper entitled "Museum Notes—Dundry Gasteropoda." This was followed by another by Mr. A. C. Pass, and the same "On the use of the Divining Rod near Bristol." Both of these have appeared above.

The first walk of the Section was on May 23rd. The members took train to Bradford (on Avon) and visited the "Bradford Clay" Sections.

In the large quarry on the right bank of the canal the clay is well seen. It forms the top of the quarry, and is about eight feet thick. Fossils are found chiefly at the base, in a layer lying on the Forest Marble and intimately joined to it. The roots of *Apiocrinus* are here "in sitû" as they grew; the columns are mostly broken up, and perfect heads even are rare, though parts and detached plates are very abundant. The other chief fossils were *Avicula costata*, *Terebratula digona* and *coarctata*, all extremely characteristic and abundant. Below the "Forest Marble" with its fragments of plant-remains and *Strophodus* teeth, are the thicker beds of the Bath Oolite, quarried for building stone. The bedding of the top beds is horizontal, but at the base throughout the quarry it is oblique, though the courses remain of the same average thickness; these diagonal joints, being all in the same direction, produce a false appearance of unconformability. Unless the circumstances are taken into account, it would lead to over-estimation of the thickness of the deposit. It is apparently due to the matter having been deposited by currents, and not an unusual feature in the Bath Oolite (see Proceedings of Bath N.H. Club, II. p. 246.) Not many fossils were found in the lower beds; *Eunomia radiata* and several small univalves, however, were obtained.

The second walk was on June 3rd (Whit Tuesday.) Members left Bristol by the 8.45 train for Woodchester. and walked thence to the Minchinhampton quarries, which are on the top of a high Down.

The "planking beds" of the Great Oolite form the top of the quarry. It is from these chiefly that such a rich fauna has been obtained, but the party were not fortunate in any of the quarries. After exploring pretty well the whole Common, they turned in to the Amberley Inn for tea, and thence to the station, after a short excursion up one of the opposite slopes.

The third walk was on September 12th. By train to Berkeley Road Station, thence on foot to Stinchcombe quarries, where a fine section of M. Lias, or Marlstone is exposed. Fossils numerous. *Ammonites spinatus* was found in the same layer with *Rhynchonella* *acuta.* Others found were, *Pleurotomaria expansa*, *Pecten equivalvis* and *demissus*, *Gryphea gigantea*, *Avicula inequivalvis*, *Myacites liasinus*, *Pholadomya*, six inches long, *Terebratula punctata;* also Belemnites paxillosus, which as usual were called "thunderbolts" by the quarrymen. From here the party walked to Dursley, a town nestled in a bay among the hills, where they had tea; they returned over Stinchcombe Hill (725 feet) to the Station.

The fourth walk was on October 16th. By train to Bath. Here they were met by the Rev. H. H. Winwood, Secretary of the Bath Archæological and Natural History Field Club, who kindly conducted the party to the cuttings on the new railway from Bath to Evercreech. First those on the Bath side of the tunnel were visited. The "Midford Sands" as they are perhaps best called, were exceedingly well seen, with the Cephalopoda bed at the top. They then walked over Combe Down in preference to going through the tunnel, and examined the Sections on the other side. At the other entrance the Midford Sands are seen again. Some good *Trigonia costata* were obtained from the Inferior Oolite beds.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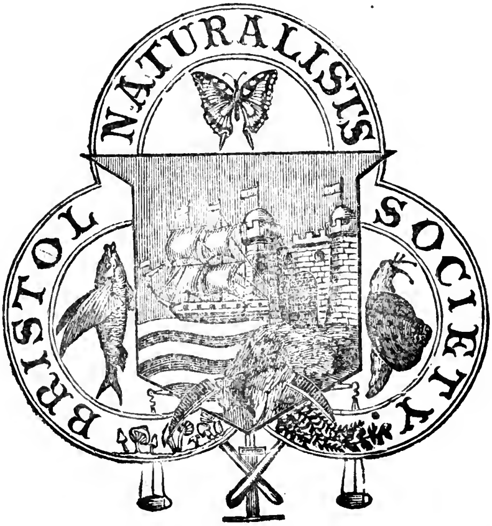

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TABLE OF CONTENTS.

NEW SERIES, VOL. I. PART II.

REPORTS OF MEETINGS AND EXCURSIONS.

[Authors alone are responsible for the various statements and opinions contained in their respective papers.]

The Society is indebted to Mr. J. E. Jose for the two lithographs which illustrate the paper on Ceratodus Forsteri, also to Mr. W. Stoddart for the woodcuts which illustrate his own paper on the Bristol Coalfield, part 2.

ERRATA.

Owing to the haste with which the proofs were revised by authors, the following corrections and emendations by authors still require to be made. [Ed]

On plates 4 and 5, read "Vol. I," for Vol. II."
Page 147, line 13 from bottom. For 461, 22," read "vol. 161, p. 511."
...... 148, ... 6 from bottom. For "have," read "has."
...... 170, ... 5. For "*Spiriferini*," read "*Spiriferina*."
...... 170, ... 6. For "*Gy*," read "*Gry*."
...... 171, ... 7 from bottom. For "position," read "condition."
..... 172, .. 18. For "*variablis*," read "*variabilis*."
...... 172, ... 10 from bottom. For "clayshell," read "clay-shale."
...... 178, .. 12 from bottom. For "*Pleuratomariu*," read "*Pleurotomaria*."
...... 182, ... 6 from bottom. For "5'' 6'''" "read 5' 6''"
...... 184, ... 7 from bottom. For "remaked," read "remarked."
.. .. 187, ... 13. For "phosphatical," read "phosphatised"
.... . 194, ... 16. For "*ven lencophœa*," read "*var leucophœa*."
...... 199, ... 2. For "Tissidens," read "Fissidens."
...... 206, ... 21. For "problems," read "problem."
...... 210, ... 32. Cancel the whole of the line.
...... 210, ... 33. For "the," read "The."
...... 211, ... 5. For "lineal, read "linear.
...... 211, ... 12. Ditto ditto
...... 211, ... 6. For "sum," "sum," read "product," "sine."
...... 213, ... 1 For sentence beginning "on the other hand," read "on the one hand, there must be taken into account the changing and constantly lessening divergence of pencils of large apertures after entering the objective: on the other hand, the opposite condition, &c."
...... 216, ... 17. For "in," read "on."
...... 217, ... 4. For "two first, read "first two."
...... 217, ... 21. For every improvement," read "every later improvement," and cancel "since."
...... 218, ... 7. For "affected," read "effected."
.. ... 219, ... 27. For "as," read "and."
...... 221, ... 16. For "In the," read "IX. In the."
...... 222, ... In note, two lines from bottom, for "Roberts'" read "Nobert's."
...... 228, ... 9. For refracted," read "refrangible."
...... 229, ... 28. For "thing," read "things."
...... 230, ... 12. For "So long as the angle, &c." read "As long as the size of aperture remains so large that, &c."
...... 230, .. 29. For "definite kind," read "prescribed form."
...... 231, ... 8. For "illuminations," read "illumination."
...... 234, ... 19. For "surface," read "surfaces."
...... 240, ... 11. For "alteration," read "alternation."

ERRATA.—*Continued.*

Page 245, line 18. Cancel "does."
...... 246, ... 27. For "content," read "contents."
...... 250, ... 1. For "operation," read "observation."
...... 251, ... 18. For "From the point, &c.," read "XXIII. From the point, &c."
...... 253, ... 2. For "content," read "contents."
...... 253, ... 6. For "in," read "or."
...... 254, ... 20. For "objective," read "objectives."
...... 255, ... 32. For pencil," read "pencils."
...... 255, ... 34. For "condition," read "conditions."
...... 260, ... 11. For "partially," read "potentially."
...... 261, ... 23. For "condensors," read "condensers."
...... 264, ... 8. For "sound," read "sand."
...... 265, ... 7 from bottom. For "Holapella," read "Holopella."
...... 271, ... 8. For "Limestone," read "sandstone."
...... 274, ... 14. For "Pisidioides," read "pisidioides."
...... 277, ... 14. For "PALMOBRANCHIATA," read "PULMOBRANCHIATA."
...... 284, ... 2. For "Albida," read "albida."
...... 284, ... 13. For "Minor," read "minor."
...... 301, .. 14. For "*Ælcistes*," read "*Æcistes*."
...... 304, ... 5 lines from bottom. For "*Fontanalis*," read "*Fontinalis*."
... 306, ... 10 from bottom. For "*amygdalima*," read "*amygdalina*."
...... 309, ... 9. For "*albipunta*," read "*albipuncta*."

On Fish Remains in the Bristol Old Red Sandstone.

BY S. MARTYN, M.D.

Read at the General Meeting, February 5th, 1875.

IN this communication on "Fish Remains in the Bristol Old Red," I wish simply to lay before the Society certain Ichthyolites found during the past two years in that formation, at its nearest point of accessibility to us; and I do so without any knowledge as to how far others may have preceded me in the same field.

The Bristol Old Red Sandstone, in the area mapped out by Mr. Sanders as our coal-field district, affords a much wider subject, both as to fossil remains and stratification, than I am now alluding to. Since, however, the Old Red Fish bed of Portishead (the position of which I was able to determine in 1867) has yielded to my unfortunately scanty opportunities a few specimens of interest in addition to those already laid before the Geological Section, I shall place these incidentally before you.

The spots which I now bring under your notice as containing Fish remains, are close at hand, and for reasons which will appear directly, an indication of them seems opportune at the present moment. Walking N.E. from Clifton across the Carboniferous Limestone of the Downs, we are, owing to the considerable dip of the strata, geologically speaking, rapidly descending; till crossing a belt (N.E. to S.W,) of Lower Carboniferous Limestone, we strike the line of the Old Red.

The first locality in which I noticed Fish remains, was the lower railway cutting below Cook's Folly, and just beyond the celebrated bone bed in the lowest Limestone, described by Lyell as "almost entirely made up of Ichthyolites." After passing through the short railway cutting in the shales, the Old Red begins with thick beds of a conglomerate of rolled pebbles imbedded in a quartzose coarse sandstone. The similarity of this to the Portishead Fish bed in general character led me to expect Ichthyolites, and the first time I looked with care (in September, 1872) some pieces were found without difficulty six feet below the top of the thick beds. I may state at once, that neither these nor the remains from the sites I am about to name, are more than fragmentary. Hitherto the question has been to me one of locality, although I do not despair of the discovery, by those who have more time, of larger and recognizable forms. The railway cutting is narrow, and of course must not be damaged in the cause of science; besides which, you have to keep close up to the rock face while the trains pass by, only just leaving room: so altogether the spot is not eligible for examination on a large scale with comfort.

The second locality is in the railway cutting above, the descending new line passing, of course, through the same section higher up. From the Old Red there I brought a number of small but unquestionable specimens. Their depth from the surface was here considerably more than I had before observed,—

one fragment occurring many feet below the lowest shales. I am informed that this section is nearly if not quite walled-up now.

A third, and much more satisfactory locality for examination, is a quarry which has been opened within the last few weeks upon the new building land of the Stoke House Estate, and in which a fish bed is now exposed. Crossing Durdham Down by the Stoke Road, and immediately on commencing the descent of the hill, the newly laid-out road diverges to the right. For several years past I have picked up pieces of Old Red with Fish remains on this road; but in October of '72 first saw these in the rock *in situ.* The new quarry is to the W. of this road, near a small old roadside quarry containing water, and actually on the line of junction between Lower Carboniferous and the Old Red. The bed from which the fragments were taken, is a very coarse quartzose stone, approaching conglomerate in structure. Its surface lies 6 feet below the red and yellow marls of the Lower Carboniferous shales. Its dip is 43° S. by E., and its height above mean sea level, 258 feet.

The fourth spot, and one which will I think also repay examination, is a quarry on the other side of the same road, about 100 feet distant. Here the same section is repeated, though the fish bed is in its upper member not more than 3½ feet from the marls. From this quarry the pieces which have long been seen in the heaps scattered about probably came.

With respect to the character of these fragments, they are for the most part simple plates of bone, either belonging to the head covering or to scales, (the marking on which has been erased by friction) and one tooth or spine. They are similar to those occurring at Portishead in close proximity to the large scales of *Holoptychius.* After the good fortune which attended careful search there, I should hope that perfect and characteristic specimens might be found here also. The obvious difficulty is that the remains are imbedded in a pebbly stone, the movement of whose particles amongst one another by the waves must have tended to break up fine structures. The stratified bands which may intervene will be well worth searching, since at Portishead they yielded a beautifully imbedded tooth and scale of *Holoptychius*. That Fish remains will be found, scattered at intervals of varying depth, is rendered probable by their occurrence in the Portishead deposit, at a distance of 6-8 feet in vertical measurement from each other.

Ceratodus Forsteri.

BY W. W. STODDART, F.G.S., F.C.S.

Read February 5th, 1875.

THE discovery of this singular fish in Queensland, is one of those curious occurrences with which the student of natural history sometimes meets.

For many years past the Rhætic beds of Aust Cliff have been celebrated for the great abundance of fossil teeth that have been collected with the bones of Saurians. More than 400 different forms of these teeth have been described under the name of Ceratodus, or horned teeth, so called from several prominences that proceed laterally from the body of the tooth (pl. 5, fig. 2). Mr. E. T. Higgins, made the largest collection of these teeth, which has been purchased for our magnificent Geological Museum.

As these were the only portion of the fish that had been found, the original nature of the Ceratodus could not be ascertained with certainty. For some time they were in the hands of Prof. Agassiz, but without any elucidation.

In 1870, the Hon. W. Forster shewed to M. Kreft, the Curator of the Sydney Museum, a cartilaginous fish that lived in Queensland, and whose teeth corresponded in every respect with those of the fossil Ceratodus.

They have been caught in the Mary, Dawson, and other rivers in Queensland, and are called by the natives "Barramanda." Two species have been found, C. meiolepis and C. Forsteri.

The Ceratodus is very nearly allied to the Lepidosiren, is cartilaginous, is a vegetable feeder, and like the Lepidosiren, lives in muddy creeks. When the hot weather sets in it buries itself in the mud, and is dug up by the natives who hold it in great esteem as food.

The Ceratodus belongs to a sub-order of Ganoids called Dipnoi, or double breathers, because it can breathe with lungs or gills, either separately or conjointly. The nostrils are situated inside the mouth (pl. 5, fig. 1).

The Ceratodus, however, differs from the Lepidosiren by—

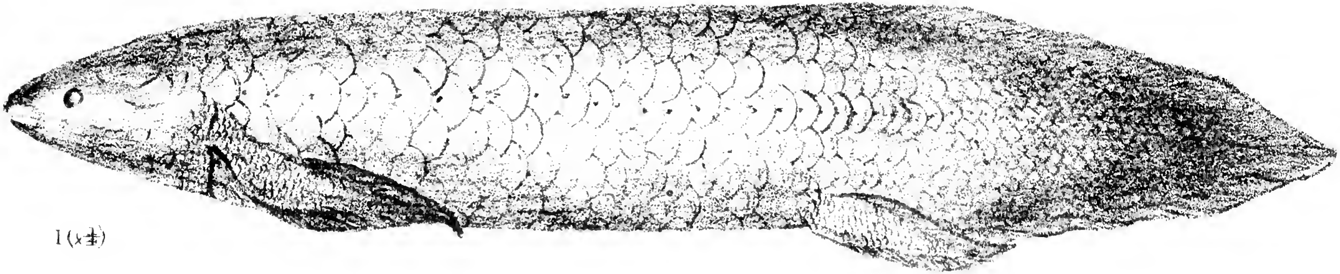
(1) The Conus arteriosus having a *transverse* series of valves instead of two *longitudinal* ones.

(2) The ovaries having transverse lamellæ, instead of being closed sacs.

(3) The teeth being distinct, although only modifications of the same type.

(4) The Ceratodus is herbivorous, whereas the Lepidosiren is a carnivorous amphibian.

Although the Ceratodus cannot be said to be a true liver out of water, yet there seems no doubt that it occasionally works its way on to the muddy banks, and in the warm weather buries itself until the return of the wet season. As seen in the figure (pl. 4, fig. 1) the posterior half of the Barramanda is surrounded by a vertical fin, which commences about the middle of the back and ends behind the ventral paddle. There are two pairs of these paddles (pectoral and ventral) which differ widely from the fins of ordinary fishes, by a close resemblance to the caudal extremity of the vertebral column. The body is entirely covered with large scales (pl. 4, fig. 2) shewing the lines of growth very plainly, and which are much smaller on the paddles and tail. The other species (C. meiolepis) is covered by much smaller scales, which constitute the principal difference between it and the present subject of our paper (C. Forsteri).



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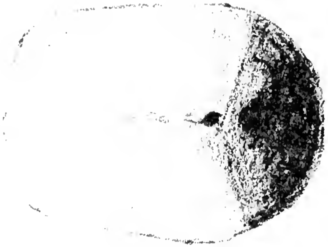

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E. Jose, Del

The latter has eighteen series of scales, five of which are above and eleven below the lateral line, while the former, with twenty-one series of scales, has six above and thirteen below the lateral line. The skeleton is cartilaginous. Wherever bony tissue appears it is always *covering* the cartilage, as for instance, in the skull, where the bony plates entirely cover the cartilage, so that the skull is nothing more than a closed cartilaginous case covered and defended by a bony defence. The muscles of the eye, for instance, pass backwards *between* the bone and the cartilage.

The spinal column is a true notochord. There are four gills on each side consisting of broad, isolated lamellæ, and attached to the walls of the gill cavity.

The lung of the Barramanda is simple and sac-like, the interior being divided into compartments by strong septa.

When the fish swims in water and breathes by means of the gills, the lung takes the place of the common air bladder. But when the water disappears, or the animal is in the mud, then the gills are useless, and breathing takes place by the lungs, which, like Batrachians, communicate with the upper part of the mouth.

For a complete account of the minute anatomy of the Ceratodus the student is referred to Dr. Günther's paper in *Phil. Trans.* 461, 22, 1872.

Our attention is, however, more particularly arrested by the teeth, on account of our familiarity with the fossil ones found at Aust.

The fossil teeth (pl. 5, fig. 2) at most have five horns only on the outer edge of the dental plate, while the recent ones have six (pl. 4, fig. 3). The grinding surface is beautifully marked with star-like punctuations, which are the terminations of the medullary canals. These canals are parallel to each other, and sometimes dichotomize, but never anastomose. The crown of the tooth is not very thick, and is separated from the other part by an extensive pulp cavity. In the fossils this pulp cavity is nearly obliterated. The horns or prolongations of opposing teeth fit each other like the teeth of a common rat-trap, so that they form a powerful grasping apparatus. Each fish has four of these teeth.

The microscopic structure of these teeth very strongly resemble those of the old Palæozoic fish—Psammodus, Ctenodus, Dipterus, Cheirodus, and Conchodus. The fossil teeth attain a much larger size than the recent, many having been found more than three inches in length. Besides these remarkably formed teeth, the Ceratodus has two vomerine teeth in the upper part of the mouth. These are simple convex, long laminæ, with serratures on the outer edge. They are inserted obliquely to the vomerine axis, and are placed at right angles to each other. The teeth of the Ceratodus have an herbivorous type, while those of the Lepidosiren are more adapted for cutting and piercing, and therefore are carnivorous. The intestines of the Barramanda are filled with partially decayed vegetables.

It is worthy of note that the nature of the habitats of the fossil fish exactly corresponds with that of the recent. They lived in dismal, muddy flats, and buried themselves in lumps of clay, and, using their lungs, breathed through a hole purposely made for communication with the surrounding atmosphere. When these blocks are broken, the interior shows beautiful casts of the scales.

These brief notes show plainly how the natural history of the Rhætic Ceratodus—at one time so strange and puzzling—is explained by the remarkable discovery of the Queensland Barramanda. It also corroborates the well-known fact that the Australian fauna have a most distinct Jurassic type.

The student of Natural History is invited to visit the unique collection of the remains of the Ceratodus in the Bristol Museum, in which every variety of the fossil teeth from the Aust bone bed may be seen in juxta-position with the recent fish, caught in the Mary river of Queensland.

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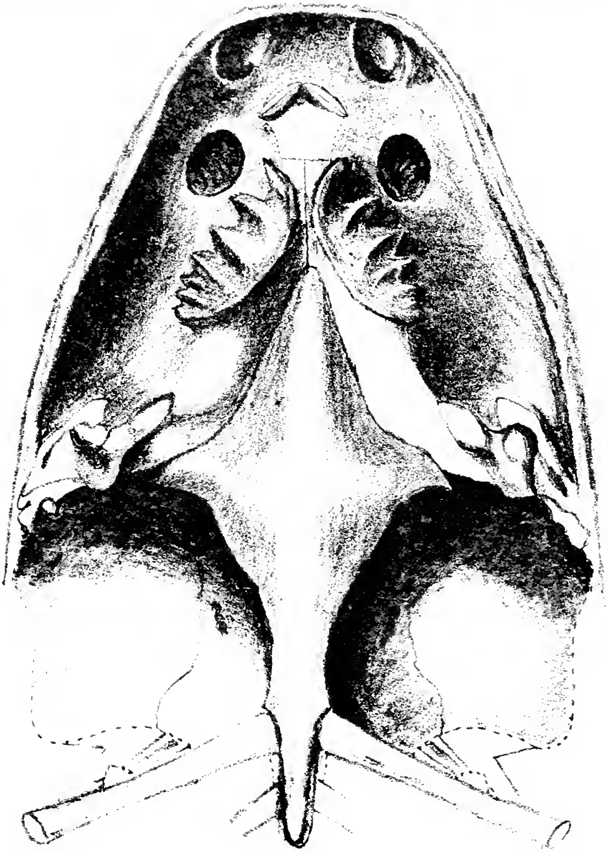

2

J E Jose Del.

EXPLANATION OF THE PLATES.

Pl. 4, fig. 1.	*Ceratodus Forsteri* (Kreft) from a stuffed specimen in the Bristol Museum, presented by the author, $\frac{1}{4}$ nat. size.
.........fig. 2.	Scale of the same, the dark part is the portion not overlapped by adjoining scales, nat. size.
.........fig. 3.	Right tooth of upper jaw of the same, nat. size.
Pl. 5, fig. 1.	Interior view of upper jaw, showing the apertures of the nostrils surrounded by the soft parts; the vomerine teeth in front, and the pair of grinding teeth behind; the pterygo-palatine and basal ossifications are seen; the dark portion behind represents the cartilaginous roof of gill cavity (after Dr. Guenther) $\frac{2}{3}$ nat. size.
.........fig. 2.	A fossil tooth from Aust Cliff (from the Higgins collection) nat. size.

On the physical theory of Under-currents and of Oceanic Circulation generally, with some account of the voyage of H.M.S. Challenger.

BY W. LANT CARPENTER, B.A., B.Sc.

Read October 1st, 1874.

[Abridged.]

THE attention of the Society was first drawn to a few simple physical principles, which entered largely into the explanation of the causes of the currents in large masses of water. The fundamental doctrine was that whenever the equilibrium of the several parts of a mass of liquid were disturbed, their inequality of pressure produced a movement for its restoration; and it followed from this, that if the disturbing cause continued to act, there would be a constant tendency to restoration, without an actual restoration of equilibrium, and hence a continuous movement would be set up. The simplest case was the formation of a "head" of water by wind blowing towards the head of a long inlet. Other causes were the alteration in the specific gravity of water, either by changes in its temperature, or in its salinity, the latter being increased by surface evaporation, and lessened by rain and fresh water. An important distinction was drawn between a *horizontal* and almost superficial circulation, produced by winds or tides, and a *vertical* circulation, in which there was an interchange between water at the surface and at the bottom.

The physical conditions of certain inland seas were then noticed. In the Caspian (which, as Von Baer had shown, formerly covered a much greater area) the level being now nearly constant, it was clear that the surface evaporation was exactly balanced by the rain-fall and river supply. The evaporation current and deposition of salt in the Karaboghaz were shown to be due solely to solar heat. In the Red Sea the surface evaporation was about 23 feet per year. Since no rivers flowed into the Red Sea, and there was a strong evaporation in-current through the strait of Babel Mandeb, it was evident that, as the salinity of the water remained the same, there must be an under-current flowing outwards through the strait. In the Mediterranean, the surface evaporation was greater than 50 inches per year, and the rainfall about 23 inches. leaving a deficiency of 27 inches. Now 27 inches depth over the Mediterranean area amounted to 508 cubic miles, or $\frac{1}{23}$ part of the volume of water supplied by the Nile. It was clear therefore, since the level was constant, that there must be an inflow from the Atlantic; and as the salinity did not increase year by year, that there must also be an outflow.

A comparison was then instituted between the temperature of the Mediterranean and the Atlantic at the same depths in the same latitudes—the temperature of the former not falling below 55° at any depth, while that of the latter continued to fall as the depth increased (2000 fms., 36°.5.) A detailed explanation was then given of the causes of, and the work done by, the upper and under currents in the Strait of Gibraltar, in which, by its temperature and specific gravity, Mediterranean water (sp. gr. 1·0292) could be easily distinguished from Atlantic water (sp. gr. 1·0268.)

The conditions of the Black Sea were then noticed. Here the river supply and rainfall exceeded the evaporation, and the sp. gr. of its water was from 1·012 to 1·014, or about half that of the Mediterranean. There was a strong surface-current running outwards, and the recent experiments of Capt. Wharton in H.M.S. *Shearwater* had conclusively demonstrated the existence of a strong under-current running inwards (from the Ægean Sea) through the Bosphorus and Dardanelles. In the Baltic, which received the drainage of $\frac{1}{5}$ of Europe where most rain fell, and the evaporation was least, a similar state of things prevailed, and the inward under-currents had been carefully investigated by Dr. Meyer, Kiel.

The thermal condition of the Sulu Sea, near Borneo, was then explained. To a depth of 400 fathoms its water had free communication with the surrounding China Sea, but below that it was cut off by reefs and shoals. Captain Chimmo, R.N., had shown that down to 400 fathoms the fall in temperature proceeded at the same rate in the two seas; but that below that depth the temperature continued to fall in the China Sea, reaching 37° Fah. at 1546 fathoms, while in the Sulu Sea it was 50° at any depth from 500° to 1778 fathoms, and this difference was attributed by Captain Chimmo to the exclusion of the deep Polar flow which lowers the temperature of the China Sea.

Mr. Carpenter then proceeded to expound the doctrine of a General Oceanic Circulation sustained by difference of temperature. He stated that a few months previously Mr. Prestwich had called attention to the fact that this doctrine had been first promulgated by Professor Lenz, of St. Petersburg, as an inevitable deduction from his observations made in the voyage of the *Kotzebue*, in 1823-6. His main conclusions, which have lately been amply confirmed by the *Challenger's* observations, were :—

"(1) The doctrine of a deep underflow of glacial water from each pole to the equator.

"(2) The ascent of polar water to the surface under the equator.

"(3) The movement of the upper oceanic stratum from the equator towards the poles.

"(4) The dependence of these movements on the disturbance of hydrostatic equilibrium constantly maintained by polar cold and equatorial heat."*

Although Arago, Pouillet, and other distinguished physicists adopted similar views, and pointed out several inferences from them, they were, in this country and in France, put aside in favour of the doctrine of a uniform deep-sea temperature of 39° Fah., which was supposed to have been established in D'Urville's and Sir James Ross's expeditions, and was accepted by Sir John Herschel.

A short description, illustrated with elaborate diagrams, which cannot well be reproduced here, was then given of the *Challenger's* temperature survey of the Atlantic, which had been characterised by competent authorities as "the most important single contribution ever made to terrestrial physics, presenting, as it does, the whole thermal stratification of an oceanic area which may be roughly estimated at fifteen millions of square miles, with an average depth of fifteen thousand feet."

The drawings exhibited represented sections of the Atlantic Ocean, drawn on two scales, like a Geological section, the vertical one being a scale of depth in fathoms, and the horizontal one being a scale of nautical miles. The temperatures at various depths being obtained by "serial soundings," were then marked upon the section, a series of "Bathymetrical isotherms" were drawn across it, different colours being used for water ot different temperatures, so that the relations of temperature and depth at the various parts of the section were evident at a glance.

The first section was from Teneriffe (28° N.) to St. Thomas's (18° N.), in which the chief points of interest were, the uniform depth, 380 fms., at which 49° was reached; and the fact that in the Eastern basin the bottom temperature was 35°.5, but in the Western (separated from it by the Dolphin rise) it was 34°.4,

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* St. Petersb. Acad. Sci., Bull v., 1847.

indicating, probably, *Antarctic* water. The next three sections were devoted to investigating the Gulf stream proper, or Florida current, and were taken from St. Thomas to Bermuda, Bermuda to Halifax, and Bermuda to New York. They showed very plainly how minute a sectional area was occupied by the Gulf stream compared with the enormous body of water alleged to be put in motion by it; and the continuity of the "cold wall" on the American coast with the cold polar underflow was pointed out, and its rationale explained. The fifth section was from Bermuda, through the Azores, to Madeira, and the sixth from Madeira, through the Cape de Verde Islands to a position in lat. 3° N. and long. 15° W., in which—although the surface temperature was much warmer—the isotherm of 40° rose from 900 fms. depth at Madeira to 400 fathoms in the equatorial position. The seventh section, which comprised the Equatorial Atlantic, was taken from the last-named position through St. Paul's Rocks and Fernando Noronha to Pernambuco, in lat. 7½° S. In this section, the uprising of polar water to the surface was clearly demonstrated (1) by the very rapid fall in the thermometer, from 78° at the surface to 40° at 300 fathoms depth, while in both N. and S. Atlantic oceans, outside the tropics, that temperature was not reached till about 800 or 1,000 fathoms, depth, and (2) by the specific gravity observations. In the North Atlantic the surface water was about 1·0272, and the bottom (or polar) water was about 1·0263, while in the equatorial Atlantic the surface water was 1·0263, and the bottom water nearly the same, 1·0261. In this section also the bottom temperature fell to 32°.4, showing the derivation of this water from an Antarctic source, to which it was subsequently traced. The last section was taken from Abrolhos Island (lat. 26° S.) to Tristan d'Acunha (lat. 26° S,), and thence to the Cape of Good Hope, thus well illustrating the thermal stratification of the South Atlantic, and clearly showing the existence of a more voluminous cold underflow than existed in the North Atlantic, probably owing to the fact that the Antarctic circle was far less land-locked than the Arctic, so that there was a more free passage for an interchange of water.

The author, in conclusion, pointed out that many of the facts discovered by the *Challenger* had been predicted by Dr. Carpenter as necessary deductions from the theory of Oceanic Circulation, and claimed support for it on this ground. He argued that this great vertical circulation could not be either set on foot or kept up by the mere action of wind and solar heat at the surface, as was maintained by the supporters of the Gulf stream theory; and he contended that polar cold was a far more potent agent in producing it, since the surface water as it cooled down sank to the bottom, thus establishing at once a vertical movement, while its place was immediately supplied by an indraught of warmer surface water. The amelioration of climate of N.W. Europe, therefore, was due, not to the Gulf stream—a mere surface current, which lost itself in the North Atlantic, and was broken up before it reached 33° W. long.—but to the north-easterly movement of a vast body of water 1,700 miles wide, and at least 600 fms. deep, as was shown by the fact that the Bathymetrical isotherms of 45° and 40° scarcely changed their position between Portugal, where they were below the normal, and the Faroe Islands, where they were above it. The only possible inference from this was that there was a northward movement of the whole stratum, to which an easterly direction was given by the earth's rotation, since the water at the equator was moving at a greater rate from W. to E. than the water north of it, and hence water coming from the equator, and bringing an increased easterly momentum, had a tendency to go towards the east.

Bristol Rotifers: their Haunts and Habits.

BY C. T. HUDSON, M.A., LL.D.

Abstract of a Lecture on Nov. 5th, 1874.

IT is now half a century or more since Ehrenberg published his great work on the Rotifera, and the classification which he then adopted still holds its ground—not because it is satisfactory, but because no one has as yet been able to supplant it by a better. Ehrenberg divided the Rotifers into three great groups, according to the forms of their trochal discs, and each group into a sub-division, according as the animals contained in it were loricated, or illoricated, and each sub-division into families—one of the chief characteristics of which was the presence or absence of red eye-spots.

Unfortunately, every character upon which Ehrenberg relied for the above classification has failed to stand the tests applied by modern research and better instruments. The trochal discs (though still not entirely understood) are seen to be very different from the simple forms figured by the Professor; the red spots are by no means always eyes—where they are eyes they sometimes disappear in the adult animals, and when they are not eyes, they are very variable in number and position: in fact, neither trochal discs nor red spots yield good characters for classification. As to the difference that Ehrenberg draws between the loricated and illoricated sub-division of each group, it looks very neat and symmetrical on paper, but this symmetry can only be obtained by applying the term *lorica* to such widely diverse structures as the hardened integument of *Brachionus*, the pelleted case of *Melicerta*, and the fluffy investment of *Lacinularia*.

Leydig and Dujardin have both studied the Rotifers, and have both tried their hands at classifying them. Leydig has added greatly to our knowledge of their structure, but his classification is even looser than Ehrenberg's. Dujardin, on the other hand, has not been a very successful observer, but he has suggested a classification which is much superior to Ehrenberg's, and will, I think, be the basis of that which will ultimately be adopted. Cope has followed on the same line as Leydig, and has improved on his predecessor, as was to be expected from his wide and accurate knowledge of the subject; and the result, with some slight modifications, is as follows:—

The Rotifers may be divided into two great groups:

I. The fixed forms.
II. The swimmers.

And the latter group may be sub-divided into

A. Those that swim only.
B. Those that swim, and also creep like a leech.

Group I. contains all the tube-making Rotifers, and naturally falls into two families, viz.—

(i.) Flosculariæa
and (ii.) Melicertadæa,

in which (i.) contains those tube-makers whose mouth is symmetrically situated with respect to their trochal discs, and (ii.) those in which it is asymmetrically situated.

Sub-division A. contains the families

(iii.) Brachionæa,
(iv.) Hydatinæa,

(iii.) being those free-swimmers which have a lorica, and (iv.)

those which are without one, while sub-division B contains but one family, viz.—

(v.) Philodinæa.

We come now to the genera, and these would be ranked in this scheme of classification as follows :—

(i.) *Flosculariæa* ....Floscularia,
Stephanoceros.
(ii.) *Melicertadæa* ....Melicerta,
Limnias,
Lacinularia,
Tubicolaria,
Œcistes,
Megalotrocha,
Conochilus,
&c
(iii.) *Brachionæa* ....Brachionus,
Pterodina,
Euchlanis,
Dinocharis,
Salpina,
&c.
(iv.) *Hydatinæa*.........Hydatina,
Notommata,
Synchœta,
Triarthra,
Polyarthra.
Rhinops,
Pedalion,
Asplanchna,
&c.
(v.) *Philodinæa* ....Rotifer,
Actinurus,
Callidina,
&c.

I have purposely omitted several of the less common genera as well as of those which have been separated from each other on the ground of red-spots, styles, caudal hairs, &c., &c., and of similar minute differences.

Of the above twenty-five genera no less than twenty-one have representatives in the ponds round Bristol and Clifton, the remaining four which I have not yet discovered, viz., *Lacinularia*, *Tubicolaria*, *Megalotrocha*, and *Conochilus*, are probably to be met with in some clean, clear, weed-clad, sluggish brook, if there is such a thing in our neighbourhood.

Floscularia campanulata is often to be met with in Garraway's pond, near the White Ladies' road, and *F. ornata* I have occasionally met with in Abbot's pond, at Leigh.

Stephanoceros Eichornii is very rare, but I have found it in Garraway's.

Melicerta ringens is to be found in many places—in the Portbury ditches, in Abbot's pond, in ditches near Portishead, &c., &c.

Limnias ceratophylli I have taken in the ponds close to the railway station at Nailsea, and on algæ growing on one of the arches of a bridge over the Frome, near the Duchesses Woods.

Œcistes crystallinus is a frequent inhabitant of Garraway's pond and of Abbot's pond. It sometimes occurs in myriads, covering the algæ and the stems and leaves of the lilies and water weeds. It is a true Melicertan with a trochal disc, precisely of the pattern of *M. ringens*, though very minute.

Œ. longicornis is also to be found, though rarely, on the algæ in Abbot's pond.

As to the various species of *Brachionus*, nearly all, including *B. Mülleri*, are to be found in the farm-yard ponds about us; the latter is only occasionally to be met with in the Bedminster ditches. It is a very large, handsome rotifer, and well worth the studying.

Pterodina patina and *P. valvata* are inhabitants of Abbot's pond, and the former is to be met with in the Float; the latter very curious rotifer, which has the power of folding its lorica like a Pembroke table, I found once in thousands round the dam gate in Abbot's pond.

Euchlanis dilata and *E. triquetra* are often to be taken among the water weeds that grow round a small spring at the head of Abbot's pond; but I have never found any species of *Euchlanis* in great numbers. This beautifully transparent rotifer is generally solitary, as also is its cousin *Salpina.*

Dinocharis pocillum is to be found in the Portbury ditches near the railway station. It is fond of the water crow's-foot.

Hydatina senta and *Triarthra longiseta* have no objection to puddles that have drained from dung heaps; the former, also, is generally to be had among the floating bits of old wood and cork that are lying at the side of the Float, while the latter is to be met with also at the bottom of the cleanest ponds.

Polyarthra platyptera I have often found in one or other of Garraway's ponds, and also in a pond near the railway at the back of a farm house in St. George's, half-way between Portbury and Pill.

Rhinops vitrea and *Pedalion mirum* belong to two perfectly new genera. The former I have found both at Abbot's pond and and Garraway's—the latter, which is the wonderful six-legged rotifer, I have never found anywhere but in the pond at the head of Nightingale's Valley and in Abbot's pond: it is often at the very bottom of the water.

Asplanchna priodonta, and a new species very similar to *A. Sieboldii,* are to be found, sometimes, in a ditch on the right hand of the road from Portbury railway station to Portbury, as well as in the ponds about Stoke Bishop. I found an amazing number of the latter once in a farm-yard pond of Mr. Harding's, close to the turnpike road.

The Philodines (except *Callidina*) are to be met with everywhere, and only call for this remark, that in spite of their being the commonest of all rotifers, their males have not yet been seen. *Callidina* has no special habitat, and is generally found in the company of the other Philodines, but is rare.

In conclusion, I have only to add that, although Bristol has but few ponds, and (so far as I know) not a single clear slow stream, yet there is ample scope (as I think I have shown by the above sketch) for anyone who wishes to delight and instruct himself by the study of these beautiful living atoms.

Notes on Trias Dykes.

BY E. B. TAWNEY, F.G.S.

Read November 5th, 1874.

GEOLOGISTS have long been aware of a remarkable Dyke on the Observatory Hill, which stands out like a wall from the mass of Mountain Limestone. It is of New Red Sandstone age, being composed of hard conglomerate, the so called Magnesian Conglomerate. Everyone who walks up the hill on the Suspension Bridge side, or who goes over the bridge, cannot fail to notice it. It is ordinarily supposed probably to be part and parcel of the Limestone, but an observant eye is arrested at once by its peculiar position. True, on a cursory inspection, it may seem to consist of Carboniferous Limestone; but looking closer we notice that the blocks of Limestone are separate, though cemented together into one rock-mass by the red or yellow magnesian paste, and cemented so firmly that the rock is tougher than the original Limestone. This is the reason of its standing out like a wall,—it has resisted denuding agencies better than the Limestone. Of course the parallel sides of the Dyke are due to the fact, that it was originally matter filling-in a fissure or crack. At the time the conglomerate was being deposited, the Carboniferous Limestone gaped slightly, in certain definite directions, and the fissures were filled in with the materials of the conglomerate, which have set into a hard compact mass. The Limestone is cut up by joints which have made it a comparatively easy prey to denuding agencies, and hence it comes that the Dyke stands out prominently, while the Limestone has been removed from around it. The direction of this Dyke is N. and S. (magnetic).

But this is by no means the only one of the kind. If we look across the river from the bridge to the escarpment at the base of the bridge pier on the Leigh side, we may see a Dyke filled in with New Red Sandstone: though small, it is plainly seen on the cut face of the rock; it has a course of about W. 17 S. by E. 17 N., cutting obliquely across the beds and nearly along the strike. The depth of this fissure, below the level of the present surface, must be about 250 feet. Again, on the Clifton side, in the roadway leading to the bridge, we may observe a number of these veins from a few inches to two or three feet wide. Their general course is N. 20 W by S. 20 E. (or magnetic N. and S). One we may observe nearly at right angles to this direction, viz , E. 20 N., and underlying at a smaller angle. The sides of the vein are generally lined with calc spar, while the New Red Sandstone fills the central part of the fissure, showing that the fissure has been open some time, and was getting gradually closed by crystalline growth of calcic carbonate, before the sediments of the New Red period had access to it. Strings of pure Hæmatite are sometimes found in the centre of the veins.

At the opposite end of the hill is another of these veins with a N. and S. direction, it contains much crystallised Calcite and a little New Red sediment.

It will be observed that the character of these Dykes is much like those, so ably described by Mr. W. Pengelly, F.R.S., on the S. Devon coast near Berry Head: they are not so numerous with us, nor, although they seem to run in two directions, have we been able to notice that one set lifts the other, or was formed at a subsequent date.

In cutting the Tunnel under the Downs through the Carboniferous Limestone, fine crystals of Celestine were obtained. Now the New Red of Bristol has long been famous for the Celestine found in it, and from the description of our collector (J. Owens) I have little doubt but that the deposit met with in the Tunnel was from a fissure filled in at the time of the New Red. The blocks to which the crystals were attached were large blocks of Carboniferous Limestone, some half a ton in weight, and were rounded and corroded, but had the paste of the Magnesian Conglomerate sticking to them occasionally; hence it was evident that the crystals were in cavities of Triassic Conglomerate which filled a fissure, some six feet wide, in the Carboniferous Limestone.

It would seem also, that we have evidence in these fissures of deposits of later age than that of the New Red. There is one near the Suspension Bridge which may be of Rhætic or L. Lias age. It is some time since the surface was cut, and it is not now very clear; but we see what may be a wide fissure (or pocket) in which blocks of Cotham-marble are found imbedded. Lias Septaria too were dug out of it in making the road to the bridge and the excavations for the bridge chains. The bulk of the infilling material seems to be greenish marl, such as occurs in the Rhætics, with a little red marl: the fissure was probably filled up in the time of the Lias. Professor Jukes* has remarked, that the Lias must have extended over all this district as it occurs on high ground round Westbury.

Supposing then that the Trias and Lias covered the Carboniferous Limestone, the question may arise, was the river gorge in existence at that time? An examination of the mode of occurrence of the Dykes will incline us to give a negative answer. We may then with more confidence attach ourselves to the

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* Geol. Mag. IV. p. 445, 1867.

opinion of Professor Jukes, that the Avon gorge was at the time it began to be formed the lowest part of the country, and therefore may have been cut by the action of river-water.

We further believe that the course of the Avon through the gorge is in intimate connection with the systems of joints in the Limestone, and that many of its bends are primarily due thereto. The drainage would naturally begin to flow along the lines of joints, and as these are mostly at right angles to each other, a tortuous course would rise; when the drainage amounted to a perennial stream, the angles where these break into one another would get rounded off, and as the river gets older its origin would get less plain.

The direction of the joints in the Sea Wall quarry are as follows— One set is N. 30 W. by S. 30 E., this corresponds with the main direction of the reach between the Sea Wall and the round point; the other cuts these somewhat obliquely, being W. 15 N. by E. 15 S., this does not differ many degrees from the direction of the reach under Cook's Folly. The reach also between the St. Vincent's Rocks and Cumberland Basin again corresponds in direction with that of the joints, being here about S. 20 E. by N. 20 W. If we may be allowed to reason back from this coincidence, though we do not pretend that it establishes the point, yet we may say it almost justifies the presumption that the gorge owes its existence to the errosive and denuding action of water, rather than to any cataclysmic throes or convulsions of nature, or even *faults* which seem certainly absent as far as the direction or course of the river is concerned.

In conclusion we may mention similar Trias Dykes in Carboniferous Limestone on the S. Wales coast. During a flying visit to the Mumbles near Swansea, we noticed precisely similar phenomena between Mumbles Head and Caswell Bay.

At the corner of Langland Bay a small Dyke was observed containing Hæmatite. The large artificial chasm near the Head forming a notch in its outline, as seen from Swansea, is simply one of these Trias Dykes which contained so much iron-ore, that it was worth extracting and taking away to the furnaces: the direction of this Dyke was N. and S.

Visitors to that coast should notice the fine "Raised Beach" which extends round the coast-line by Caswell Bay.

Notes on the Lias in the Neighbourhood of Radstock.

BY E. B. TAWNEY, Assoc. R. Sch. Mines.

Received November 5th, 1874.

HAVING lately had occasion to arrange the Lias fossils in the Bristol Museum, we observed a number from Mungar, which can scarcely hitherto have been referred to their proper horizon. The set of Mungar fossils in the Museum was collected by the late Mr. S. Stutchbury, who placed them all in the Middle Lias, an arrangement which has been endorsed apparently, by subsequent curators. Some of them were left undetermined, and, indeed, otherwise it would have been surely seen that it was a question of other beds besides the Middle Lias.

Taking the Ammonites only, we have the following species in the collection:—*A. Johnstoni, Conybeari, Sauzeanus, Jamesoni, Maugenesti, ibex, brevispina.* The latter four of these are certainly Middle Lias species, but the others are indubitably L. Lias forms, and an inspection of the list shows that we have to deal with more than one zone of the L. Lias.

With the Brachiopoda from the Radstock district there was a similar confusion, *e.g.*, all the specimens of *Spiriferina Walcottii* were placed with the Middle Lias fossils.

It became therefore desirable, before attempting to rectify these anomalies, to examine the beds and collect fossils *in situ* in order to see whether Ammonites—which in other localities are not only confined to the L. Lias, but characterise often special levels in these beds—were in the Radstock district found in Middle Lias beds mingled with M. Lias fossils. Special attention was to be similarly extended to the distribution of the Brachiopoda.

I regret much that the time we have been able to devote to these investigations has been so limited, and our opportunities of collecting fossils so comparatively few—it is desirable to be on the spot when the quarrymen are getting out fresh stone, and before it is broken up into roadstone and carted away—our list of species is much smaller than it might be, for we have forborne to name imperfect specimens, the identification of which was uncertain; the beds are evidently rich in species, and will repay the careful collector.

The result of such examination as I have been able to make is that there is no confusion in nature between the Middle and L. Lias—they remain distinct; the mistake, apparently, has been that of the collector and classifier, who mingled together the fossils of different beds, either because he did not recognise the fossils, or was misled by the beds not wearing the usual appearance to which he was accustomed.

It is necessary to state that Mr. C. Moore, F.G.S., has both collected from and written on these beds, but it seemed desirable to work at the quarries first, before making myself acquainted with the precise words of this veteran Lias geologist, so as to form an independent opinion. This I have done, and am happy to think that my views of the beds are not in any important respect at variance with anything expressed by that eminent authority. One only regrets that he has not been able to give more details concerning the Radstock beds in the two Papers* in in which he touches on the subject.

By way of description, then, of the Lias in this district, I propose to bring forward sections observed in quarries at different parts, as much as possible working out the fauna of each bed by tracing it from quarry to quarry, and noting every fossil found *in situ*. We neglect, for the most part, fossils of which we do not know the precise parent bed, our object not being to note a long list, but to determine the exact bed in which certain well-known fossils occur. Much fuller lists of fossils will be found in what Mr. Moore has written.

Few and imperfect as our observations have been, we have been able to determine something of the range of Ammonites and Brachiopoda, which was the main object: not that I can pretend to have advanced knowledge under this head beyond a point known to Mr. Moore, but our observations are, at any rate, independent.

In a quarry scarcely out of the town of Radstock, we have the following section :—

The lower part of this series, from the "Sun-bed" downwards, is "White Lias." As we found scarcely any fossils *in situ* we have not given measurements in detail, either here or in following sections, but White Lias fossils are to be found on the refuse heaps—we may mention *Monotis fallax* in this case. The "Sun-bed," with its level shelf, is found in all cases where the White Lias is seen, so far as I know. The quarry is not worked down to the Rhætic shales, which cannot be far below.

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* "On abnormal conditions of Secondary deposits when connected with the Somersetshire and S. Wales coal-basin, and on the age of the Sutton or Southerdown series." By C. Moore, F.G.S., Q.J.G.S., XXIII., pp. 449-556 (1867).

"On the Middle and U. Lias of the S. W. of England." By C. Moore, F.G.S., Proc. Som. Arch. and N. H. Soc., XIII., pp. 119-232 (1867).

Quarry at Radstock, near the Wells Road.

h	28½ft.	Grey clay with phosphatic concretions	*Spiriferina Walcottii, Rhynchonella variabilis, Gryphæa arcuata, &c.*
i		Darkgrey limestone, 1½ft. thick.	*Spiriferini Walcotti, &c.*
		Grey shaley clay.	*Gy. arcuata.*
		Grey limestone—another thick bed.	
		Nodular limestones, several beds amounting to a few feet in thickness.	*Lima gigantea.*
		31 limestones, frequently with clay partings, mostly greyish white in colour. The lower beds are called "Corn-grits" by quarrymen.	Near base, *Ostræa Hisingeri,* *Modiola minima.*
u	1′ 9″ to 2 ft.	Cream-coloured limestone with a bluish grey core—"Sun-bed" of quarrymen. Splits into five beds, top bed of the White Lias.	
	3′6″	Whitish or cream-coloured argillaceous limestones, nine beds.	
	5″	Pale grey laminated clay.	
	3 ft.	Cream-coloured limestones.	

Above the White Lias we have 28ft. of beds, which are certainly Lower Lias; further, we have here represented the Planorbis and Bucklandi zones. *Ammonites planorbis* we have found on the stone heaps, and the beds of this zone are represented by those immediately above the White Lias. *Ostrea Hisingeri (liasica)* and *Modiola minima*, which occur at this level, are characteristic shells of the zone.

The middle part of this quarry is inaccessible, except at one end, and there it is difficult to obtain much, as that end has not been worked for some time. I cannot pretend now to draw any line between the Planorbis and higher zones in this quarry, even if such exists. At some future time the middle beds of the quarry may become more workable. Towards the top the beds contain *Lima gigantea* and *punctata* abundantly, and belong possibly to the Bucklandi zone.

We pass now to the two top beds, which are interesting from the extraordinary abundance of *Spiriferina Walcottii* which the clay at the top contains. We shall be able to recognise this bed again all through the district, both lithologically and by the fossils contained therein. We have used letters, arbitrarily chosen, for marking such beds as we have observed in more than one quarry—the same letter to signify identity of bed throughout. Mr. Moore, translating a German designation literally, has called this the "Spirifer-bank." Thus we have had no difficulty in finding the most important Brachiopod of the district: the question then comes—Where are we to classify bed (**i**)? Mr. Moore places it in the L. Lias, and there is no doubt but that he is perfectly right. Tracing this bed to other quarries we find fossils in it which lead us to place it in the Bucklandi zone, but this we shall have to refer to again. This was one of the questions we had to settle—the exact position of *Spiriferina Walcottii*—and we find that the specimens thereof in the Bristol Museum have been wrongly placed in the Middle Lias. If we turn to the catalogue of fossils in the Museum at Jermyn Street* we find a similar misapprehension (*l.c.* p. 183). We maintain that the Survey palæontologist has wrongly catalogued this species from the M. Lias of Radstock and omitted it from the L. Lias. It is true that we have found this species in imperfect specimens in the M. Lias of Banbury, and Mr. Day has noticed it from the M. Lias of Charmouth, but we have not noticed it in this position in our present district; at all events, failing to refer Radstock specimens to the L. Lias is a palpable omission.

This case of 28 feet for the L. Lias is the largest development of these beds that we have met with round Radstock. The lithological position of the beds, however, is considerably different from that of the Bristol Lias.

The following quarry has yielded me more fossils *in situ* than most of the others; it is, therefore, introduced here as giving much information concerning the zones of life:—

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* Catalogue of collection of fossils in the Museum of Practical Geology. By T. H. Huxley, F.R.S., and R. Etheridge, F.G.S., 1865.

Section of Bowldish Quarry above Welton.

M. Lias.	**e**	6″-9″	Grey limestone. sometimes with grains of iron-ochre. Splits into two beds.	*Am. armatus, Oppeli.* *Ter. punctata.* *Rhy. variabilis.* *Discina.*
Lower Lias.	**f**^{1}	4″	Bluish and brown clay.	*Am. raricostatus.* *Gry. Maccullochii.*
	f^{2}	4″-5″	Nodular bluish argillaceous limestone.	*Belemnites.*
	f^{3}	8″	Blue and brown clay.	*Belemnites penicillatus.*
	g	4″-5″	Greenish grey limestone, regularly bedded.	Fish scales.
	h	2′-6″	Blue clay, sandy and indurated at base with phosphatic concretions.	Fossil wood. *Sp. Walcottii. Ter. punctata. Am. raricostatus. Gry. arcuata. Rh. variabilis. Am. Bucklandi.*
	i	9″	Thick grey limestone with a few phosphatic concretions near the top. Fossils near top chiefly.	*Am. Sauzeanus.* *Sp. Walcotti. Gry. arcuata.* *Rhy. variablis Lima gigantea.* *Ter. punctata. Pleurot. expansa.*
		$1\frac{1}{2}$″	Brown clay parting	*Gry. arcuata.*
	k	3″-4″	Paler grey limestone.	.
	l	1′-3″	Thick pale grey limestone, weathering yellowish white, splits into two.	*Lima gigantea.* *Pinna.*
		1″	Brown clay parting.	
	n	2″	Yellowish white limestone.	*Lima punctata, tuberculata, Pinna.* *Gry. arcuata. Unic. cardioides.*
		1″	Brown shaley clay parting.	
	p	1″	Pale whitish limestone.	*Lima punctata. Astarte.* Fish scales.
		$\frac{1}{2}$″	Clay parting.	
		2″-$2\frac{1}{2}$″	Yellowish white limestone.	*Unic. cardioides. Ost. Hisingeri.* Fish scales.
		1″-2″	Brown clay-shell.	
		3″-4″	Hard, greyish limestone.	
		1″-2″	Clay with a thin limestone band.	
White Lias.	**u**	1ft.	Thick pale blue limestone, weathers cream-colour. Splits into several beds. (" Sun-bed.")	
		5′-6″	Cream-coloured or whitish argillaceous limestones, with a few clay partings.	A few fossils, *Modiola, &c.*
		6″	Light grey clay shale.	
		2ft.	Cream-coloured argillaceous limestones.	

The fossils found *in situ* in each bed we have placed alongside, but we must combine the fossils obtained from several quarries in order to get a view of the contents of any one bed.

Bed (**u**) is recognised at once as the "Sun-bed," or top bed of the White Lias. Mr. Moore has remarked on the constancy with which the White Lias is found throughout the district, and as the lowest Lias beds thin off sometimes, leaving higher beds reposing on the Sun-bed, he has the right to claim a quasi-unconformability between Lower and White Lias. The latter shows an exposure of 9ft. in the present state of the quarry.

Above we have 7½ft. of L. Lias, in which the Planorbis, Bucklandi, and Raricostatus zones are represented, but not at all in their usual comparative development. The Ostrea and Planorbis beds are those immediately above the "Sun-bed." True, we have not found this Ammonite *in situ*, but from the other fossils and from the analogy between these and similar beds in other sections to be referred to presently, we shall not be far wrong in considering about as high as bed (**l**) to belong to this zone. Beds (**i**) and (**h**) we place with confidence in the Bucklandi zone, from the abundance of *Gryphea arcuata*, the Ammonites, and other fossils in this and other quarries. This is the *Spiriferina Walcottii* level, and this fossil is particularly abundant here. Bed (**h**) is the same interesting mass of clay that we met with in the former quarry. As it is more accessible here we have added to its list of fossils, and adding up the fossils found in it through the various sections, we shall get an idea of the richness of its contents. The lower part of this clay especially contains numerous phosphatic concretions, and the numerous fossils are generally entirely filled with this phosphatic matter, being found commonly as interior moulds; the calcareous investing shell is, however, occasionally preserved.

The assemblage of fossils in this bed is also interesting. We have here a passage, apparently, or a mingling of Bucklandi fossils with those of higher zones. We have in this bed *Am. bisulcatus* (several varieties), *Bucklandi*, *multicostatus*, &c.;

Gryphea arcuata, fossils characteristic of the Bucklandi zone, and with them we find *Am. raricostatus*, which is usually supposed to be restricted to the top zone of the L. Lias. We shall see from another section that bed (**g**) represents the Obtusus zone, so that *Am. raricostatus* has passed through this. There is thus an overlapping of the Ammonite zones. The reason, apparently, is that during the long period represented by the Bucklandi zone (which includes over 100ft. of beds on the Glamorganshire coast) there was in our district an extraordinary dearth of sediment, so that a few feet of clay and limestone here represent a long period in time, and the life conditions required by the fauna of the upper zones of the L. Lias having come on during the interval, the latter fauna appears commencing in the same bed in which the *Am. Bucklandi* was still a tenant. There really was not sufficient sediment to be the burial ground of distinct zones of life. When the climate, sea currents, or other conditions altered, the migration of fauna took place without there being any physical signs of the lapse of time by the accumulation of detritus. That such a lapse of time is here represented we have a right to infer from finding in one bed Ammonites which generally occur in zones, and separated by a considerable thickness of beds. It becomes also plain that it is not the case here, as Mr. Moore has remarked, that the greater part of the Bucklandi beds have been cut away, or that the Obtusus zone has been cut away, and so on. We maintain that they are all here, more or less, in the district, for we have found most of the Ammonites which characterise these zones in the L. Lias.

The bed which comes above the clay is (**g**,) of a dark greenish blue colour, with rather a laminated structure, at times, but the heart of the bed is very tough. It contains Fish scales here, and is the level of *A. obtusus* and *planicostatus*. Above this we have clay (**f**$_3$,) with *Belemnites penicillatus*, Sow.; then a bed of irregular nodular grey limestone (**f**$_2$), which divides the clay here, but does not seem to be constant. In the clay above (**f**$_1$) we have found *A. raricostatus*, which is here in its proper place, and

Gryphea Macculloch i. The three divisions of (**f**) may be considered to represent the Raricostatus zone. We thus have had four zones of the L. Lias represented in this section.

Bed (**e**,) we consider, belongs to the M. Lias. It is formed of two bands, which form the top of the quarry, as seen at present. The stone is grey, but with admixture of the grains or shots of yellow iron-oxide, which is so common in the M. Lias here. We have found *Am. armatus* here, which is usually reckoned characteristic of the base of the M. Lias. We have also found *A. raricostatus*, but this may probably be a derived fossil. The base of the bed is partly conglomeratic, apparently, having phosphate nodules which have also, seemingly, been worked up again. We shall have to note this again. This bed has also yielded to us an Ammonite which we do not happen to have found *in situ* elsewhere. It has a keel like *A. Guibalianus*, D'Orb.; and the ribs have also the character of that species, but it has a far narrower umbilicus. We have ventured to identify it with *A. Oppeli*, Schlœn. The keel does not show on the internal cast. We have two imperfect specimens: one is seven inches in diameter. The lobes and saddles, as far as preserved, seem to agree with the type. We also found here a minute *Discina*, not $\frac{1}{8}$ inch diameter.

We do not attempt to follow any topographical order in one visit to the sections, but are taking now quarries which show us continually ascending beds. After seeing the whole series we shall then go to sections, which will take us through many of the same beds again, but hereby we shall get more complete information as to the distribution of species in the various beds.

Retracing, then, our steps somewhat towards Radstock by a road which leads to Clan Down, we soon arrive at a quarry below the coal-pit on Clan Down.

In this quarry we have unmistakable Middle Lias. It lies upon the Spiriferina clay, the top beds of the last section being absent here. Bed (**e**) which we call the Armatus zone or base of the Middle Lias, is noticeable again for containing phosphatic

Section at Clanning's Quarry, Clan Down.

M. Lias.		5ft.	Rubbly yellowish-white iron-shot limestones	*Am. Jamesoni* *Am. Henleyi* *Am. latecostatus* *Avic. inequivalvis* *Pecten subulatus* *Inoceramus* (*casts*)	*Ter. numismalis* *Rhy. rimosa*
	e	5″-8″	Hard grey and white mottled limestone, with phosphate nodules and derived L. Lias fossils.		
L. Lias.	**h**	6″	Grey clay with phosphatic concretions and occasional limestone nodules.		*A. Bucklandi.* *Sp. Walcottii.*
		4″	Two thin greyish-white limestones with clay partings.		
		8″	Dull yellowish-white limestone.		
		2″	Brown clay parting.		
		8″	Two whitish limestones with clay partings.		
White Lias	**u**	1′-1′ 6″	Thick light-grey smooth limestone with conchoidal fracture (Sun-bed).		
		4ft.	Cream-coloured limestone		

concretions with L. Lias Ammonites. Mr. Moore has already pointed out (Q.J.G.S. xxiii, p. 474) that "the bottom bed of the marlstone" (I should prefer to reject this word for the Radstock district) "is conglomerate, and contains *A. raricostatus* and other shells, which appear to have been removed from the lower zones," an observation which shows how thoroughly this eminent authority is conversant with the beds. His explanation seems to me exceedingly probable, for we notice that the L. Lias Ammonites are generally fragmentary and nearly always imbedded in phosphatic concretions, or consist of the same phosphatic matrix; we imagine all fossils in this condition to have been derived from the clay (**h**). Some of the phosphatic nodules are well rounded and have evidently been worked up again. Only in one case, viz., in a quarry near Huish Farm, have we noticed in this bed a L. Lias form composed of the yellow oolitic matrix, which is characteristic of the M. Lias here: it was an *Am. raricostatus* which may perhaps be a legitimate inhabitant of this bed;—if so, it would be another case of the overlapping of Ammonite ranges.

The remaining beds of the M. Lias are yellowish iron-shot limestone, the little grains of yellow ochre, producing an oolitic appearance, and at first sight the beds might easily be mistaken for some in the Jurassic series. They are not regularly bedded and separated by partings like the L. Lias, but are more or less massive, and break up into irregular blocks. The Ammonites we have obtained *in situ* are *A. Jamesoni, latecostatus*, and *Henleyi;* hence the Jamesoni zone is represented as well as the Armatus zone. The order in which the Ammonites occur is therefore normal, but it seems impossible to draw hard and fast lines; the zones blend into one another, the species overlapping in a more marked way than when the deposits are less condensed. Even at Charmouth where the M. Lias is so thick, Mr. Day has remarked (Q.J.G.S. p. 296) on the great range of some Ammonites, *e. g. A. fimbriatus* passes up through some hundreds of feet. I fancy that extended observations and increased acquaintance with the contents of strata, will tend to modify our somewhat crude way of drawing hard and fast lines. Mr. Moore's observations seem to me to have an especial value in this respect.

The Brachiopoda found *in situ* here are *Terebratula numismalis* and *Rhynchonella rimosa*: we have not noticed these species at all in the L. Lias, and consider them therefore confined to the M. Lias round Radstock. As we meet with other species we shall return again to the subject of the range of the Brachiopoda.

Below the M. Lias is seen the Spiriferina clay with its phosphatic concretions and the same fossils as in the other sections, —only the most fossiliferous lower portion is here present.

The Middle Lias forms the top of the quarry as we have seen, but on the map of the Geological Survey it is coloured as Lower Lias. Even in the new edition of sheet 19, which bears the names of some of the most distingiushed officers of the survey, we notice this anomaly. In one part of the map the M. Lias has been recognised and distinguished by a separate colour, but in the Radstock district it has been confounded with the L. Lias. This is more or less of a defect, and would have been obviated by a little attention to palæontology; there would have been little difficulty in drawing the lines if the sections had been properly studied. This fusion is continued throughout the district.

We may now pass to the quarry at Mungar which at one time was so rich in fossils. Unfortunately it is not worked for road-stone now, and the lower beds are covered up with refuse and clay. All that is to be seen at present is about 8ft. of the M. Lias, brownish-white oolitic limestones with some that are greyish and hard, particularly in the heart of the stone. The beds are thick and break irregularly. We do not see the base, but the bed (**e**) must be present as fragments of it are lying about. We are told by those who have seen the beds exposed, that there are a few feet of L. Lias and then the White Lias. It was the latter that was used for the roads, and the trollies of stone were run out through the arched way that is now partly closed up. Close to the top of the quarry is found abundantly *A. Maugenesti* (and var. *Valdani*), also *A. Henleyi* and *fimbriatus* occur at the same level. *A. Jamesoni* seems to occur throughout. We also have *A. ibex* and *brevispina;* Belemnites are very abundant, but not very easy to extract entire; those in my collection I attribute to *Belemnites paxillosus* and *apicicurvatus.* Of Brachiopoda, *Rhynchonella rimosa* and *furcillata* are fairly abundant. Other fossils are *Astarte, Inoceramus ventricosus, Pholadomya ambigua, Pleuratomaria expansa.* Littorinæ and other minute Gasteropods are to be found in a beautiful state of preservation—we have only a few in our possession. These beds represent the lower zones of the M. Lias, and perhaps the upper zones may be unrepresented; yet I found one specimen which I take to be *A. spinatus,* it has all the characters of that species except the serrations on the keel,—its imperfect state in that quarter prevents any confidence in its determination.

A few hundred yards north of the Mungar quarry is a brick-yard in which a considerable thickness of blue clay is seen. The top 10 feet are brownish and blue clays, the lower 8 feet a dark blue stiff clay. Nodules of argillaceous Iron-ore are scattered through it, with septaria, but we could not find any fossils. We presume these clays to be Upper Lias. The late Mr. Lonsdale reckoned the Upper Lias near Camerton to be about 100 ft. thick, and Mr. Moore (*loc. cit.* p. 471) estimates it on the further side of the canal at Camerton, at 40 ft.; it is probably not more than this at Mungar.

Having now taken a first glance at the various divisions of the Lias in the district, we may next examine a few more sections to add to our knowledge of the contents of the different beds. Near Mungar on the road between Paulton and Midsomer Norton is the quarry of Phyllis' hill; it may perhaps be the same one that Mr. Moore calls "Section in Mungar Road Quarry" (*loc. cit.* p. 474) whence he obtained some very interesting fossils; he remarks also that "only three beds 18 in. in thickness occurring between the Rhætic and M. Lias formations represent the great thickness of interposed beds elsewhere."

Section at Phyllis' Hill.

M. Lias.		2'-3'ft.	Brownish white oolitic limestones somewhat disturbed and mixed with surface soil	*Ter. numismalis* *Phol. ambigua*
L. Lias.	**f**	3″	Greenish brown clay	*A. raricostatus*
	g	2″-3″	Thin grey limestone band	*Am. planicostatus, obliqecostatus* and young *A. oxynotus* (?)
		1″	Brown clay	
	g^3	5″-7″	Blue argillaceous limestone	*A. obtusus* young *A. oxynotus?* *Arca*
	h	1ft.	Grey brown clay with phosphatic nodules	*A. Bucklandi* *A. Sauzeanus* *A. obliquecostatus* *A. raricostatus* *Nautilus* *G. arcuata* *Unic. cardiodes* *Pleuromya* *Sp. Walcottii* *Rhy. variabilis* *Ter. punctata*
White Lias.	**u**	2′ 2″	Cream coloured compact limestone with blue heart (Sun-bed) splits into 3 beds	
		4′ 6″	Cream coloured limestone, 12 beds with a few clay partings.	

We have considered the clay (**f**) as L. Lias, but the specimens of *A. raricostatus* found therein were phosphatised and may possibly have been worked up again; still this clay seems so intimately united to the bed below which we know to be L. Lias, that it seems more convenient to class it as such. The bottom bed of the M Lias being absent, there may have been a slight denuding action between the deposition of some of these beds; the clays seem rather washed into one another, but this may be only surface action.—The bed (**g**) contains *A. planicostatus* abundantly, it has also a small sharp-backed shell which may be the fry of *A. oxynotus;* in other sections it contains *A. obtusus.* This latter Ammonite we find here in the Limestone (**g**^{3}). We have one fine specimen 7 inches across, so that there are proofs here of the Obtusus zone. The clay (**h**) is the Spiriferina horizon. Fossils are very numerous, and consist chiefly as casts in phosphatic material. The amount of phosphate of lime in this bed must be very considerable, and if it existed uniformly at a slight depth might be important economically.

I am greatly indebted to the Hon. Treasurer, Mr. W. W. Stoddart, F.C.S., City Analyst, for the following analysis of a concretion from this bed:—

Calcic carbonate	23.11
,, sulphate	1.49
,, phosphate	47.12
Iron-peroxide	0.88
Alumina	12 16
Silica	7.10
Moisture	8.14
Bituminous matter	trace
	100.0

The lower beds of the Lias (Planorbis zone) are absent. The "Sun-bed" follows immediately below the clay (**h**), which is the sole representative, even of the Bucklandi zone. About

7-feet of White Lias are seen. If the quarry was worked deeper we should come to the Rhætic Shales, which are seen in several railway sections about here. The Cotham landscape-bed, which forms the base of the White Lias in the Bristol district, has been noted by our President, Mr. W. Sanders, F.R.S., in his map, near Welton, and other localities in the area.

In Ham quarry, near Paulton, we get some of the lower beds again.

Section at Ham Quarry.

			Disturbed M. Lias, fragmentary.	
L. Lias.		2′ 6″	Blue clay, with one or two Limestone layers.	
	h	2′ 6″	Brownish grey clay, with phosphatic concretions and fossils, at the base chiefly.	*A. Bucklandi.* *Gry. arcuata.* *Sp. Walcottii:*
	i	2′ 2″	Thick bluish-grey Limestone.	*Lima gigantea, punctata.* *Pinna.*
		2′ 6″	Greyish white Limestones, 6 beds with brown clay partings.	*Lima punctata.* *Am. planorbis.*
W. Lias.	**u**	1′ 4″	“Sun-bed.”	
		4 ft.	White Lias.	

We have seen that bed (**i**) belongs to the Bucklandi zone, but in this quarry, on the stone heaps, we found *Am. planorbis*, *Terebratula punctata*, and *Ostrea arietis* in blocks, which apparently came from this bed. The Ammonite therefore extends up into the Bucklandi zone. We consider the beds below as the proper representatives of the Planorbis zone; but the question wants much more working out.

From Timsbury we have obtained a good many fossils. Brachiopoda are abundant in the L. Lias here.

In this section, between the White Lias and bed (**i**), there are more than twice as many beds as in Bowldish quarry, but still only about half as many as in the first section noticed at Radstock.

Section in Quarry below Timsbury.

		Soil with scattered blocks of M. Lias.	
	1ft.-1′ 6″	Brownish grey clay.	
g	4″-6″	Greenish gray limestone.	*A. obtusus, ziphus, planicostatus.* Fish scales. *Avic. inequivalvis.*
	2′ 4″	Brown laminated clay.	
	2″	Hard band of indurated clay.	
h	5″ 6″	Stiff blue clay, at base sandy and with phosphatic concretions.	*A. Sauzeanus, Sp. Walcottii, Pecten subulatus Belemnites penicillatus* *Nautilus* *Ter. punctata. Gryphea arcuata.* Fossil wood
i	2′ 3″-2′ 6″	Thick grey limestone.	*Rhy. variabilis. Sp. Walcottii, rostrata. Ter. punctata, cornuta, Gry. arcuata. Lima succincta, Hermanni. Am. Sauzeanus, obliquecostatus.*
	½″	Brown clay parting.	*Gry. arcuata. Lima Hermanni.*
	3″-4″	Pale grey limestone.	
	1″-2¼″	Clay shales with layer of limestone nodules.	*Lima succincta.*
	8″	Pale greyish limestone.	
	2″	Brown clay parting.	*Gryphea arcuata. Lima gigantea.*
	6″-8″	Pale bluish limestone.	
	1″	Brownish clay parting.	*Lima gigantea.*
	2″-3″	Pale bluish limestone.	*Lima gigantea, Hermanni.*
	½″	Clay parting.	
	10″-1′ 2″	Greyish white limestone.	*Pinna L. gigantea. Unic. cordioides.*
	2″	Yellow clay parting.	
	4″-5″	Yellowish white irregular limestone, with a thin parting.	*Pleuromya.*
	6″-7″	Greyish white limestone, with a thin clay parting.	*L. gigantea.*
	3″	Greyish white limestone.	
	1½″	Clay parting.	
	6″	Greyish white limestone.	
	2″	Clay parting.	
	2½″	Grey white limestone, with a thin parting.	
	6″	Greyish white limestone.	
	4ft.	White Lias.	

Perhaps from the abundance of the genus Lima, with its three if not four species, part of these beds belong to the lower part of the Bucklandi zone, as bed (**i**) with its abundance of *A. Sauzeanus* certainly belongs to the upper. But others near the base certainly represent the Planorbis zone, as we have obtained the latter Ammonite in a quarry close here, in similar beds lithologically ("corn-grits")—we do not happen to have found it however in this quarry; from the state of the quarry we have not been able to attack these beds to advantage, nor had the opportunity of seeing any stone got out from them.

Ammonites angulatus we have not been fortunate enough to collect anywhere in the district, so that we offer no conjectures about the Angulatus zone. It is probably not developed, as the "corn-grits" belong for the most part to the Planorbis zone: this will be alluded to below as further evidence was obtained from the Huish quarries.

Bed (**i**) is remarkably rich in Brachiopoda, both in individuals and in species. *Spiriferina Walcottii* is found in this bed throughout the area. Here we have also *Sp. rostrata, Rhynchonella variabilis, Terebratula punctata,* and *cornuta.* In determining the latter species I have endeavoured to follow Davidson's monograph (Pal. Soc.) and if I am right here, *T. cornuta,* Sow. would seem to take the place of *Ter. cor. Lam.* which occupies an analagous position on the continent.

I am indebted to Mr. R. V. Sherring, of Hallatrow, for the loan of Brachiopoda from this section: in his collection I have determined *Sp. Walcottii,* abundant, *Sp. rostrata,* nineteen specimens, *Sp. Muensteri,* three specimens, (I consider this only a variety of *S. Walcottii*), *T. punctata,* six specimens, *T. cornuta,* ten specimens.

The quarrymen tell me that all these species come from bed (**i**), and from comparing the specimens with those I have obtained *in situ* in the bed, one may believe their statement. *T. cornuta,* it will be seen from the section, I found *in situ*; it is usually considered a M. Lias species, so that its position here is noteworthy.

Sp. rostrata is also usually considered to be from the M. Lias, it seems certainly to be rare in the M. Lias of this district, but is common in our L. Lias here. In a block off a wall near Welton, I obtained the following fossils, viz. :— *Sp. Walcotti*, two specimens, *Sp. rostrata*, five specimens, *Ter. cornuta*, one specimen, *Rh. variabilis*, two specimens, with *Lima tuberculata*, *punctata*, *pectinoides*, *Pecten subulatus*, *Gryphea arcuata*, *Cardinia attenuata*, *Listeri*: the two species occurring in the same block with fossils decidedly from the L. Lias. There is therefore no doubt about *Spiriferina rostrata* and *Ter. cornuta* being found in the L. Lias—the horizon being the upper part of the Bucklandi zone.

Bed (**i**) graduates insensibly into the clay (**h**,) the top of the Limestone containing the phosphatic nodules occasionally, which are so characteristic of the basal part of the thick mass of clay. Higher up the clay is blue grey, stiff and with few fossils.

The bed (**g**) though thin is important. It has yielded Ammonites which fix its position at once in the Liassic series. We have mentioned above that it represents the Obtusus-zone,—the proof of this we obtained here. On one occasion we found a finely weathered example of this species, on another we came upon quite a nest of Ammonites, including *A. obtusus*, six young specimens, *A. planicostatus* about as many, and a fine specimen of *A. ziphus*. We notice that these three species occur together on plate 406 of the "Mineral Conchology." We have them again together on a block which we obtained from Lyme Regis.

Our specimen of *A. ziphus*, 3½ inches across, agrees so well with the description of *A. Dudressieri*, D'Orb. that we must consider the latter name as merely a synonym. Quenstedt has before remaked on their apparent identity (Jura. p. 97.) but because the French type was supposed to be from the U. Lias (an error, it has been shown) he feared to unite them. Another example of that reasoning in a circle which is the bane of geologists. Moreover the young whorls of this species are not to be distinguished from *A. planicostatus*, so much so that Sowerby in the letter-press to plate 406 considers them one species.

We shall devote only a few words to the Camerton section as as it has already been noticed by Mr. Moore (*loc. cit. p.* 471). The excavation in the hamlet of Medycat is both stone quarry and brick yard. At the top of the section are 7½ft. of stiff blue clay, this is whence Mr. Moore obtained such a fine collection of Foraminifera; as this clay is well developed in the sections above given at Timsbury and Ham, these organisms should be in equal abundance there. The base of this clay is the Spiriferina bed, it contains the same fossils and phosphatic masses that we have noticed before. I did not see bed (**g**) *in situ*, from the unfavorable state the quarry was in at the time of my visit; only pieces of it were to be seen on the spoil heaps, but no doubt it occupies the same position as in the previous section. Below (**h**) are two grey Limestones, the upper one is bed (**i**) of former sections, and contains the same fossils, *Lima succincta*, *A. sauzeanus*, &c. Below these come five beds of greyish white Limestones, separated by clay partings; these we consider to represent the Planorbis zone probably. We found *A. Johnstoni* and *Ostrea Hisingeri* (*liasica*) here, moreover we found *A. Johnstoni* (*torus*) in a grey limestone, probably the bed next below (**i**), so that in this case the Ammonite would seem to pass up into the bed above what we are disposed to consider the Planorbis beds. We must mention, however, that Mr. Moore considers all these as Bucklandi series, and says the Planorbis beds are altogether wanting. Perhaps this eminent authority on the Lias may be induced to give us some further details concerning these lower beds. Next comes the "Sun-bed" and 17 beds of Limestones making according to our measurements 8½ft. of white Lias. In slabs of White Lias on the heaps we found *Avicula fallax*, *Pecten Valoniensis*, *Cardinia* (casts) *Modiola minima* and other fossils.

We proceed now to give some notes on a section on the south side of Radstock, where the Planorbis beds come evidently quite in contact with the middle Lias, the Bucklandi beds being apparently absent altogether. Near Branch Huish there are two quarries at least where this may be seen,—we take the quarry near the Frome Railway.

Section at Huish, Radstock.

U. Lias.		2-3ft.	Yellowish and brown clays.		
M. Lias.		1′ 6″	Pale grey yellow-shot limestone, with a clay parting at base.	*Myacites.* *Astarte.* *Cardinia concinna.*	
		6ft.	Light yellow, rough, iron-shot limestones, with two clay partings.	*Belemnites paxillosus, &c.* *Nautilus* *Am. Jamesoni.* — *ibex.* — *hybridus.* — *brevispina.* — *Oppeli.* — *Grenouillouxii.* *Gryphea Maccullochi.* *Pecten subulatus.* *Inoc. ventricosus.* *Astarte.* *Phol. ambigua.* *Pleurot. expansa.* *Ter. Waterhousii.* — *subovoides.* — *numismalis.* — *punctata.* *Rhy. tetraëdra.* — *rimosa.*	
	e	1″-5″	Pale marly limestone, with dark phosphatic concretions.	*Amm. raricostatus* (phosphatised)	
L. Lias.		7″–9″	Pale bluish white or flesh-coloured limestone.	*Am. planorbis.*	"Corn Grits."
		1″	Brown clay parting.		
		1ft.	Two beds of pale limestone with a brown sandy parting.	*Am. planorbis.* *L. gigantea.*	
		1ft.-1′ 3″	Four beds of pale yellowish argillaceous limestones, with four brown clay partings.	*L. punctata.* *Myacites.*	
		1′ 2″	Three beds of pale yellowish-white argillaceous limestones, with two clay partings.		
W. Lias.	**u**	2ft.	Thick cream-coloured White Lias ("Sun-bed"). Splits into several beds.		
		5ft.	Cream-coloured limestones. Many thin beds.		

In this section we have at the base about 5ft. of ordinary white Lias on which is the "Sun-bed." Above this come the "Corn-grits" of the quarrymen; that these here represent the Planorbis zone is quite plain, for the Ammonite is found *in situ* even in the top bed and within an inch or two of the bed (**e**,) which we take as the base of the Middle Lias. The Ammonite is quite abundant, and very good specimens may be obtained. Bed (**e**) is easily found by its being mainly a mass of phosphatic concretions, dark grey in colour, imbedded in a pale marl, and forming thus a well-marked dark line in the rock. Where the rock is weathered the hard phosphatic concretions stick out of what is seen to be a soft marly Limestone; but where freshly cut, the divisions between the beds are not well marked, and the line of black included concretions is the chief feature that divides the Middle from the Lower Lias. Immediately below this level occurs *A. planorbis*, while above are M. Lias Ammonites and Belemnites. We noticed one case of *A. raricostatus* here, but as it was entirely phosphatical, it may probably be considered a derived fossil. In a quarry not far off we found it in bed (**e**) in a state which pointed perhaps to its being an inhabitant of the bed itself.

This section differs thus from preceding ones, in that the Planorbis zone follows immediately below the M. Lias,—the Bucklandi and Obtusus zones with the Spiriferina Walcottii-bed being absent.

The M. Lias is here altogether about 8 feet thick, and contains an interesting assemblage of fossils. We have seen fragments of a large Ammonite with a very square form of whorl, which seems somewhat allied to *A. quadrarmatus,* Dum. The latter has two rows of strong tubercles at the angles of the back, and is therefore different from the Radstock fragment, which has only one row. We hope that an entire specimen may shortly be obtained. We also have a broken specimen of *A. Oppeli* eleven inches across. Brachiopoda are also fairly abundant. We may cite *Ter. Waterhousii* and *numismalis* as characteristic of our M. Lias; also a form which we take to be *T. subovoïdes* (Rœm.) it is so constant in its form that it seems perhaps entitled to the rank of a distinct species: it is more elongate than *T. punctata,* but I am by no means sure that it has not been included by Mr. Davidson under that species. *Spiriferina rostrata* also occurs in the M. Lias here. Again *Rhyn. tetraedra* sparingly, also characteristic of M. Lias. The top beds of the M. Lias have a little tendency to lamination and split up into flags. They are full of a small *Pleuromya* and a fine Astarte which seems allied to *A. subtetragona*, Mu.; it invariably, however, leaves its shell imbedded, and comes out of the rock an internal mould, so that it is not easy to obtain specimens. The top of the quarry is formed of 2 to 3 feet of clays, which form a part of the Upper Lias Clays apparently.

The table which follows is intended to summarize our observations on the distribution of Ammonites and Brachiopoda in the district. Separate columns are given to the quarries selected, which are grouped under the headings of Lower and Middle Lias. Where it has been possible to give the exact bed in which a fossil was found, the letters used for that bed are cited in the column; but where a specimen was not found *in situ*, or in the case of the M. Lias, where the section has not been divided up into beds, an asterisk is used to denote the occurrence of species. In other respects the table will be intelligible of itself.

In conclusion we hope that others will be found to help work out the life-history of the Lias in this district. It has an interesting facies, and as to fossils is the richest that we know of in some respects. There are in the M. Lias evidently a variety of forms to reward the searcher, both of beautifully preserved Gasteropods and Ammonites. The Lamellibranchs and Belemnites require careful collecting, and will no doubt also repay the worker. At present we have indication of several species insufficiently preserved for identification.

TABULAR LIST OF AMMONITES AND BRACHIOPODA.

SPECIES.	*L. Lias.*							*M. Lias.*				
	Camerton.	Radstock.	Bowldish.	Phyllis Hill.	Timsbury.	Ham.	Paulton.	Huish.	Mungar.	Phyllis Hill.	Bowldish.	Clan Down.
Ammonites armatus (Sow.)	...	...	...	..	...	...	...	..	...	...	e	...
.... ibex (Qu.)	...	...	...	...	...	...	...	*	*	...	...	...
.... brevispina (Sow.)	...	...	...	...	..	...	..	*	*	...	...	...
.... Oppeli (Schlœn)	...	...	...	...	..	...	...	*	...	...	e	...
.... Maugenesti (D'Orb.)	. .	...	..	...	...	...	...	*	*	..	...	...
.... (?) spinatus (Sow.)	...	...	...	...	...	..	...	...	?	...	...	...
.... hybridus D'Orb.)	...	...	...	...	...	...	...	*	...	...	...	...
.... fimbriatus (Sow.)	...	...	...	...	...	...	...	...	*	...	...	...
.... laticostatus (Sow.)	...	...	...	...	...	...	.	*	*	...	...	*
.... Jamesoni (Sow.)	...	...	...	...	...	...	...	*	*	...	...	*
.... Grenouillouxii (D'Orb)	...	...	...	...	...	...	...	*	...	...	...	...
.... raricostatus	*	...	hf	hf	...	*	...	e	...	...	...	...
.... planicostatus (Sow.	...	...	g	g	g	...	...	...	...	...	...	...
.... obtusus (Sow.)	...	..	..	g3	g	...	...	...	...	...	...	...
.... ziphus (Hehl)	...	...	...	..	g	...	...	...	...	...	...	...
.... obliquecostatus (Ziet.)	i	...	...	ghi	ih	...	...	...	...	...	...	...
.... bisulcatus Brug.)	...	...	h	h	...	i*	...	...	...	...	...	...
.... Sauzeanus D'Orb.)	i	...	ih	h	ih	*	...	...	...	...	...	...
.... Johnstoni (Sow.)	*	...	...	...	..	*	..	...	...	...	...	...
.... planorbis (Sow.)	...	*	...	...	*	*	...	..	...	...	...	...
Discina	...	..	...	...	...	...	...	...	...	...	e	...
Terebratuta Waterhousii (Dav.)	...	...	...	...	...	...	...	*	.	...	...	...
.... numismalis (Lam.)	...	...	...	...	...	...	...	*	...	*	*	*
.... punctata (Sow.)	*	*	ih	h	ih	*	...	*	*	...	e	...
.... subovoides (Rœm.)	..	...	...	...	...	...	...	*	...	...	...	...
.... cornuta (Sow.)	...	...	...	...	i	...	...	...	...	...	...	...
Rhynchonella variabilis (Schl.)	i	*	ih	...	ih	...	...	...	...	e	...	...
.... rimosa (Buch.)	...	...	...	...	...	...	..	...	*	...	...	*
.... furcillata (Theod.)	...	...	...	.	...	...	...	...	...	...	...	...
.... tetraedra (Sow.)	...	...	..	...	...	...	...	*	...	...	...	...
Spiriferina Walcottii (Sow.)	ih	h	ih	h	ih	ih	...	..	. .	...	...	...
.........var. Muensteri (Dav.)	...	...	...	...	i	...	...	...	...	..	...	..
..............rostrata (Schl.)	...	...	...	...	i	...	...	*	*	...	...	...

Geological Distribution of some of the Bristol Mosses.

BY W. W. STODDART, F.G.S.

Received December 5th, 1874.

NATURAL selection is strikingly manifested in the localities chosen by plants of all classes and orders. Some prefer Limestone, while others select the sandy soil of the Triassic or Devonian formations. Some inhabit the driest spots, while an equal number are never found except in wet and marshy places. Indeed, so well marked is this fact, that the nature of the ground is betrayed to the Geologist by the plants with which he meets. It would be idle to seek for the *Salicornia*, *Glaux*, or *Salsola* except on the sea shore, or the brine springs of Cheshire and Worcestershire. The *Digitalis* marks the presence of Sandstone, while *Hutchinsia* and *Arabis* indicate Limestone. The botanist knows that if he wishes to find specimens of *Draba*, *Saxifraga*, or *Linaria cymbalaria*, he must search the tops of the neighbouring walls, while the rubbish heaps must be visited for *Tussilago*, *Hyoscyamus*, and some species of *Sisymbrium* and *Polygonum.*

As with the Phanerogams, so is it with the Mosses. A temporary alteration of the soil will often introduce genera which were not previous inhabitants of that particular locality. The *Funaria* so regularly follows the lighting of a bonfire that the French call it La Charbonniere, and many species of *Splachnum* can only be gathered on the dung of Oxen and Foxes.

Mosses are the most ubiquitous of plants. Every part of the globe is a home for them, from the Arctic to the Antarctic circles. They however prefer a cold climate to the hot and dry regions of the equator. The same species, as a rule, inhabit the same parallels of latitude, many of our Bristol Mosses being found in North America and the northern half of the continent. Some will not grow except at a considerable altitude, as the *Conostomum boreale* which is a Scotch moss never found at a lower elevation than 3000ft. above the sea level.

The remarks before made respecting the relation of the higher classes of vegetation to the geological nature of the soil, apply with equal force to the Mosses. Thus many species of *Tortula* and *Bryum* choose sandstone, *Schistidium* the trap, while other species of the same genera will only flourish on limestone. A most interesting confirmation of the truth of this has been long known to the German botanists. In that country boulders occur, which in former ages have been transported by icebergs from extreme northern latitudes. On these may be seen *Andræa Rothii*, *Grimmia trichophylla*, and *G. leucophæa*, but are not to be found on the surrounding soil.

The very great geological variety of the environs of Bristol, has induced the author to make observations of this nature on the plants of our district, and the following list of Mosses has been copied from his note-book. We are favourably situated for moss collecting. The author's own herbarium contains 47 genera and 127 species, a number which of course would be greatly increased by the labours of other collectors, and a more complete catalogue made than the one now offered of those which are remarkable for selecting their own peculiar and favourite soil.

LIMESTONE.

Archidium phascoides (Brid.)
Wood below Portishead; South side of Avon, opposite Cook's Folly; Westbury (in fruit.)

Anacalypta lanceolata (Röhl.)
On walls at Westbury; St. Vincent's Rocks.

Anomodon viticulosus (H. and T.)
Westbury; Brockley Combe.

Bryum cœspiticium (Linn.)
Common on walls.

Bryum intermedium (Brid.)
Common on walls.

Bryum cernuum (Hedw.)
Common on walls.

Bartramia calcarea (B. and S.)
Cheddar.

Bartramia Œderi (Swartz.)
Ladies' Bay, Clevedon.

Cinclidotus fontinaloides (P. Beauv.)
Near Sherbourne Reservoir.

Cylindrothecium Montagnei (B. and S.)
Durdham Down; Leigh Woods; Weston.

Didymodon luridus (Hornsch.)
Eastfield.

Eucalypta vulgaris (Hedw.)
Frequent everywhere.

Eucalypta streptocarpa (Hedw.)
Portishead; Bedminster; Stoke Bishop.

Funaria Hibernica.
Leigh.

Funaria Muhlenbergii (Schwœg.)
Redland; Henbury; Kingsweston.

Gymnostomum tortile (Schwœg.)
Durdham Down; Stoneleigh Camp; Nightingale Valley.

Grimmia pulvinata (Smith.)
Common everywhere on rocks.

Grimmia orbicularis (B. and S.)
Durdham Down.

Hookeria lucens (Dill.)
Near South Buttress of Suspension Bridge.

Hypnum lutescens (Dill.)
Rocks on both sides of the Avon.

Hypnum crassinervium (Tuyl.)
Black Rock Gully.

Hypnum striatulum (Sprud.)
St. Vincent's Rocks; Leigh Woods; Westbury, &c.,

Hypnum circinnatum (Brid.)
Frequent on walls.

Hypnum murale (Dill.)
Shirehampton; Penpole; Ashton.

Hypnum tenellum (Dicks.)
Frequent on walls and rocks.

Hypnum polymorphum (Hedw.)
Great Quarry.

Hypnum delicatulum (Linn.)
Durdham Down; new Zigzag; Leigh Woods.

Hypnum rugosum (Dill.)
Durdham Down; Westbury.

Hypnum commutatum (Dill.)
Worle Hill

Hypnum uncinatum (Hull.)
Redland; Ashton; Steep Holmes

Hypnum molluscum (Dill.)
Frequent.

Hypnum incurvatum (Brid.)
Redland.

Hypnum depressum (Bruch.)
Black Rock Gully; Shirehampton; Ashton.

Hedwigia ciliata (Hedw.) ven. lencophœa.
Stoke Bishop; Cheddar; Durdham Down.

Mnium cuspidatum (Hedw.)
Leigh Woods; Cook's Folly.

Mnium stellare (Hedw.)
Durdham Down.

Neckera crispa (Dill.)
Near Brockley Combe.

Orthotrichum cupulatum (Hoffm.)
Blaize Castle.

Orthotrichum anomalum (Hedw.)
St. Vincent's Rocks.

Phascum recurvifolium (Dicks.)
Brockley; Cheddar.

Phascum crispum (Hedw.)
Blaize Castle.

Seligeria pusilla (B. and S.)
Henbury.

Schistidium apocarpum (B. and S.)
Frequent on rocks.

Trichostomum crispulum (Bruch.)
St. Vincent's Rocks; Ashton; Westbury.

Trichostomum mutabile (Bruch.)
Leigh Woods, Portishead.

Trichostomum rigidulum (Sm.) var densum.
Eastfield.

Trichostomum flexicaule (B. and S.)
Cheddar.

Tortula rigida (Schultz.)
Frequent.

Tortula gracilis (Schu.)
Durdham Down.

Tortula fallax (Hedw.)
Leigh Woods; Stoke Bishop.

Tortula tortuosa (W. and M.)
St. Vincent's Rocks; Westbury.

Tortula revoluta (Schu.)
Leigh.

Tortula convoluta (Hedw.)
Horfield Quarries.

Tortula muralis (Hedw.)
Frequent; also var S. rupestris.

Weissia verticillata (Brid.)
Stones on drain near Nempnet

SANDSTONE.

Atrichum undulatum (Linn,) var. abbreviatum.
Frome Glen.

Bartramia pomiformis (Hedw,)
Crews Hole.

Bryum nutans (Schreb)
Stapleton.

Bryum annotinum (Hedw.)
Beggar Bush Lane.

Bryum lacustre (Brid.)
Portbury.

Bryum raseum (Schreb.)
Stapleton; Portishead; Portbury.

Ceratodon cylindricus (B. and S.)
Stapleton.

Campylopus densus (B. and S.)
Flax Bourton.

Dicranum crispum (Hedw.)
Winterbourne; Shirehampton.

Dicranum rufescens (Turn.)
Stone Gifford; Thornbury.

Dicranum cerviculatum (Hedw.)
Winterbourne; Chelvey; Flax Bourton.

Fontinalis antipyretica (Linn.)
Stapleton.

Fissidens viridulus (Linn.)
Sea Mills.

Gymnostomum tenue (Schrad.)
Failand.

Hypnum albicans (Dill.)
Portishead.

Hypnum salebrosum (Hoffm.)
Shirehampton.

Hypnum velutinum (Dill.)
Common.

Hypnum cœspitosum (Wils.)
Shirehampton; Heath House; Weston-in-Gordano.

Leptobryum pyriforme (Hedw. sp.)
Stapleton.

Pogonatum nanum (Brid.)
Bank of Frome River, Stapleton.

Polytrichum aloides (Hedw.)
Frome Glen.

Polytrichum commune (Linn.)
Frome Glen.

Phascum serratum (Schreb.)
Shirehampton.

Phascum cuspidatum (Schreb.)
Frequent in New Red Sandstone Fields.

Seligeria recurvata (B. and S.)
Stapleton.

Schistidium maritimum (B. and S.)
Yatton.

Schistostega osmundacea (W. and M.)
Pill.

Trichostomum canescens (Hedw.)
Stanton Drew.

Trichostomum tophaceum (Brid.)
Portishead.

Trichostomum tortile (Schrad.)
Leigh Woods.

Trichostomum homomallum (B. and S.)
Mendips, near Shipham.

Tortula cuneifolia (Dicks.)
Portishead.

Tortula marginata (B. and S)
Quarry opposite Cook's Folly.

Tortula subulata (Brid.)
Failand.

Tortula ruralis (Hedw.)
Failand.

TRAP.

Grimmia leucophœa (Greville.)
Damory Bridge.

ARGILLACEOUS SOILS.

Bryum carneum (Linn.)
Cook's Folly.

Didymodon rubellus (B. and S.)
Cook's Folly.

Tissidens taxifolius (Hedw.)
Sneyd Park.

Gymnostomum squarrosum (N. and H.)
Horfield.

Pottia minutula (B. and S.)
Sea Mills ; Cheddar.

Racomitrium ellipticum (B. and S.)
Ashton.

Tortula ambigua (B. and S.)
Bedminster; Ashton; Patchway.

Tortula aloides (B. and S.)
Sneyd Park; Eastfield; Cook's Folly.

Tortula unguiculata (Hedw.)
Rather frequent.

Weissia mucronata (B. and S.)
Shirehampton—Watery Lane.

A Contribution to the Theory of the Microscope, and the nature of Microscopic Vision.

By DR. E. ABBE, Professor in Jena.

Read before the Bristol Microscopical Society, December 16*th*, 1874.

PREFACE BY THE TRANSLATOR.

Under the title here given, Dr. Abbe has published in the 9th vol. of *Schultze's Archiv fur Mikroscopische Anatomie*, the results of some important investigations which I cannot but think must prove of great interest to all who value the microscope as an instrument of scientific research. In offering a translation of this essay to the readers of our journal, I venture to remark that the exposition therein contained of optical principles involved in the phenomena of microscopic vision, and their application to the construction of the microscope, deserve to be as widely known amongst microscopists and students of physical science in England as in Germany. It will also be seen that many facts of real practical value are presented in a new and intelligible point of view by Dr. Abbe's interpretation of the manner in which the microscopic image is formed, and of the appearance of certain details in this image, which he shews to be due to the influence of the internal structural constitution of the object examined upon rays of light transmitted through it.

In this translation a few paragraphs relating to illuminating apparatus, and the conditions upon which their effects depend, are omitted, as being only supplementary to the principal subject, and also because reference is therein made to doctrines which are somewhat at variance with English opinion and practice, and which require for their proper understanding further explanation than is afforded by the curt mention of them in Dr. Abbe's essay. To the reader who is not familiar with the teaching of the German writers on the microscope, the reference made to the treatise of Nageli and Schwendener conveys no information; and this part of the subject is therefore omitted in the present communication.

With this exception, however, the essay has been carefully rendered, and the sense of each paragraph strictly conveyed. It has been my aim to express the author's views as nearly as possible in his own words, that his claim of originality might not suffer by false or loose rendering of his meaning; and also because such a claim carries with it an equal responsibility to the reader as well as to the author for accuracy of translation, particularly when the subject is professedly treated as one belonging to exact science, and attention claimed on the special ground of novelty of doctrine. If the absence of that ease and simplicity which is thought essential to popular handling of a subject be matter of regret, I fear that any deficiency in the original will be still more felt in the translation ; for I am fully conscious that in adhering to an almost verbal transcript of idiomatic expressions which have no exact English equivalent, I do not lighten the labour of the reader. Yet in no other way can a circumlocution still more objectionable be avoided, or that significance of meaning preserved which so many German expositors of science seek to convey by a peculiarity of style which is scarcely compatible with fluent and unlaboured English, though strikingly characteristic of German habit of thought, and of the genius of the German language,—a style, namely, which throws an atmosphere of minute qualification around every positive statement; and which, though expressive of thoroughness and conscientiousness, has to the unlearned the effect sometimes of obscuring rather than clearing the view. To use a German proverb, "One cannot see the wood for the trees!" Unfortunately, however, translation loses point in proportion as it fails to render back the many-sided aspect of the original.

Having read Dr. Abbe's essay with that pleasure which attends the acquisition of new ideas, (vainly sought for in English works on the microscope) I feel a natural desire to introduce the author's views to an English public, so far as a plain and, I trust, faithful translation may afford the means of introduction; and shall be amply repaid for any trouble incurred in executing my self-imposed task if the researches here recorded should prove as instructive and acceptable to others as to myself.

That no one may be deterred from reading these pages by the supposed abstract nature of the subject, or its technical treatment, I may here state that the mathematical demonstrations on which Dr. Abbe builds his theory, and the detail of experimental method pursued by him in the practical portion of this enquiry, are not communicated in the present article, which is simply a general statement of results. A more detailed account is promised in an article to be published in the *Jena Journal of Natural Sciences.*

H. E. FRIPP.

SECTION I.—*The construction of the Microscope on a theoretical basis.*

I. In our handbooks of micrography occasion is sometimes taken to allude to the fact that the construction of the microscope, and its progressive improvement, have been almost exclusively matters of empirical practice,—that is to say, of skilful and persevering trials prosecuted by experienced, practical men. Now and then, perhaps, the question may be asked, "Why is it that the theory which enables us to give a sufficient account of the mode of action of a microscope *when it is made*, does not at the same time serve as the foundation of its construction? Why do we not construct this kind of optical instrument by help of calculation founded on theoretically deduced formulæ as has been so successfully done since the time of Frauenhofer for the telescope, and in more recent times for the optical part of the photograph-camera?"*

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* In corroboration of the fact here alluded to as currently accepted in Germany, the following extract from Lardner's "Chapter on the Microscope," (paragraph 11) in his *Museum of Science*, may find a suitable place as shewing the same fact from an English point of view.

"Now the solution of this problem presented to scientific and practical men the most enormous difficulties—difficulties so great as to have been regarded by some of the highest scientific authorities of the last half century as absolutely insurmountable. Happily, nevertheless, the problem has been solved; (!) and without disparagement to the great lights of science, we must admit that its solution has mainly been the work of practical opticians. It is true that the general principles upon which the form and material of the lenses depend, were the result of profound mathematical research; but these principles were established and well understood at the moment when the practical solution of the problem was by scientific authorities themselves pronounced to be all-but impossible. Opticians, stimulated by microscopists and amateurs, then applied themselves to the work; and by a long series of laborious and costly trials, attended with many and most discouraging failures, at length arrived at the production of optical combinations which have rendered the microscope one of the most perfect instruments of philosophic research, and one to the increasing powers of which we can scarcely see how any limit (!!) can be assigned."

The historical truth of Dr. Lardner's statement is not affected by its being somewhat out of date; on the contrary, it remains valid for the years intervening between that date and the present time. We still look for an adequate scientific theory of the microscope in our present micrographic literature. And the rules and methods of construction now employed in such optical combinations as the microscope objective, are known only to those who have made personal sacrifices of time, study and money to attain it. In a word, the most successful and important achievement of optical *science* is a trade secret. It is scarcely possible to urge a stronger proof of the value

The persistence of empirical practice is commonly attributed to the technical difficulty, or supposed impossibility, of maintaining the requisite accuracy in executing the prescribed measurements of the several constituent lenses of a microscope objective.* At first sight this explanation seems plausible enough, since the minuteness of dimensions, especially in the case of high power objectives, may well cause the difficulty of working such measurements to the required nicety to appear almost insuperable. Nevertheless, the objection does not apply; on the contrary, a careful consideration of the scientific and technical means at the disposition of the practical optician, and a critical comparison of the various kinds of difficulties serving as a guiding thread and key to the theoretical discussion of the conditions influencing them, have led me to the conclusion (supported since by actual successful results) that lenses and systems of lenses of which each separate part has prescribed dimensions, can be thus executed with an exactitude that fairly ensures correct action, and with greater facility than any other mode of procedure offers for the fulfilment of the same conditions with equally good results; and consequently it only needs that the calculations for each separate element of the optical effect should be *correct* to secure, with good execution, the success of a given theoretical construction.

In the workshops of T. Zeiss, of Jena, the construction of the various objectives, from lowest to highest power, is regulated by strict calculation (based upon accurate analysis of the material) for each single part, each curve, each thickness of glass, each degree of aperture; so that all guess work and "rule of thumb" is avoided. The optical constants of each piece of glass used are

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of such researches as form the subject of Dr. Abbe's essay, or a stronger argument for extending their publicity, if only for no other reason than to uphold the independence, and reassert the dignity of pure science after its almost forced abdication and temporary weakness.

* Throughout this essay the German terms "Objective" and "Ocular" are retained as more suitable than the equivalent English terms "Object-glass" and "Eye-piece."

previously obtained from trial-prisms by means of the spectrometer, in order to compensate any accidental variation of material by suitable alteration of the construction. Each constituent lens is ground as nearly as possible to its prescribed dimensions and accurately fitted. In the highest-power objectives only is there a single element of the construction (a lens distance) left variable, in order that unavoidable slight deviations from accuracy of the work may be adjusted. And thus it has been shewn beyond dispute that a well-grounded theory, combined with rational technical processes, which utilise all the means that physical science can offer to practical optics, may be successfully substituted for empirical practice, even in the construction of the microscope.

II. In the course of the studies which led to the results above stated, it became apparent that the theory of the microscope as hitherto propounded fails in several important points. In the first place, the manner in which the conditions of perfect projection of an image and the causes of its imperfect projection have been discussed, proved altogether inadequate to the real facts of the case as they occur in the microscope. The circumstance that an amount of angular aperture, which is unknown in any other instrument, comes here into question, renders the accepted ideas of "aberration" entirely useless, even for a moderately critical estimation of any given microscope already constructed, to say nothing of any attempt to determine beforehand the effect of combinations not yet executed.

To obtain the data needful for a trial of this last kind, a theoretical analysis of the action of a system of lenses constructed with large angular aperture, had to be carried out on a far wider mathematical basis and in much more precise detail than has been hitherto done. And in doing this it became manifest that the correct performance of any combination of lenses for the microscope which should meet all demands satisfactorily, depends upon an unexpected number of conditions, each independent of of the other, a proper estimation of which would not be possible without introducing various questions into the theory of the microscope which at present form no part of it.

To develope such a theory more fully in the directions here indicated, was mainly a mathematical task involving problems to be solved by the aid of established principles of Dioptrics. Experiment and experience were concerned in the enquiry only so far as it was necessary to become acquainted with the actual form in which each separate source of error, as indicated by theory, might be recognised in the microscope when finished, and also to estimate rightly their very unequal significance in the practical use of the instrument. On the other hand, a fresh deficiency in our present theoretical knowledge revealed itself, which could only be supplied by fresh experience. The nature of this deficiency is indicated in the uncertain, and often contradictory, views held respecting the significance of angular aperture and the so-called "defining" and "resolving" powers of an objective. To remove all uncertainty, and to obtain clear insight into the conditions which operate here was a *conditio sine qua non* for any successful attempt to develope a theory in the sense above mentioned; for upon the effect supposed to be obtained by angular aperture depends the whole direction and solution of the problems. Each single proportion in the construction will differ altogether, according as it is calculated for an objective—say, of 40°, 90°, or 150° aperture. But what kind of effect was to be expected remained wholly doubtful, so long as no accurate account of the real significance of these factors ("definition," and "resolution,") could be given.

III. The result of investigations which were undertaken independently, in order to bring these questions to some issue, was the discovery that an important feature in the optical functions of the microscope had been hitherto overlooked, for in all previous explanations or interpretations it has been accepted as a self-understood proposition that the formation of an image of an object in the microscope takes place in every particular, according to the same dioptric laws by which images are formed in the telescope, or on the receiving surface of a camera; and it was, therefore, tacitly premised that every optical function of the microscope was determined, just as in these other instruments, by the geometrically traceable relations of the refracted rays of light. A rigorous examination of the experiences upon which this traditional distinction of "defining" and "resolving" powers is founded, has shewn that the proposition, though apparently consistent with fact, is not admissible. It holds good, indeed, for certain cases, capable of definite verification, but for the generality of objects, and particularly for those objects on which the microscope is supposed to exhibit its highest quality of performance, it appears that the production of microscopic images is closely connected with a peculiar and hitherto neglected physical process, which has its seat in and depends on the nature of the *object* itself, although the measure of its effect stands in direct dependence upon the construction of the *objective*. The results which follow from these facts have a direct bearing on the most important problems in micrography; they shew the existence of an entirely specific function of angular aperture, and in connection therewith present clearer and truer notions respecting those two factors of so-called defining and resolving power which constitute the optical capacity of the microscope, and from the correct perception of which every condition on which its performance depends may be accurately determined. Hence, also, may be gathered practical rules for the construction of the microscope on rational principles, as well as suggestions for suitable methods of testing it when made. On the other hand, an exploitation of the newly-gained ground by further experiments and researches led to deductions respecting the general nature of microscopic vision. Thus it became possible not only to fix the limits of the visible, beyond which no further resolution of microscopic structure could be expected, but also to bring to light a fact of general application, namely, that a microscopic image which may be entirely free from error in itself, and therefore be supposed to represent in all cases the true constitution of an object—a proposition on which all interpretation of microscopic vision has been hitherto based as indisputable—nevertheless does *not* do so for a whole class of objects and observations.

The occasion and purpose of this theoretical and experimental enquiry, the leading points of which have been here noted, was mainly a practical one—namely, to obtain some safe guide in determining a formulary of conditions concerned in the calculation of a system of lenses; but it has grown of itself to the dimensions of a complete theory of the microscope, which touches every chapter of micrographic doctrine, and has even added fresh chapters. In its close connection with the technical construction of the microscope this theory has proved serviceable in two ways. On the one hand, the rigorous demands imposed by the practical aim of the work have compelled investigations of a kind which no one would have felt bound to undertake, merely because he was writing a treatise on the microscope; on the other hand, the actual construction of microscopes on the principles deduced from theory has brought into application the most sensitive tests to which any theoretical considerations of this kind could be subjected.

The details of these studies are communicated in full in the 8th vol. of the *Jena Journal of Medicine and Natural Sciences*,* but a condensed summary of results is now offered, in the hope that it may prove acceptable to many practical microscopists. The same order and method of enquiry is pursued here as in the more detailed communication—namely the discussion first of all matters that relate to the purely dioptric conditions; and in the second place the consideration of the new factors before mentioned, and the share they take in the total optical performance of the microscope. It must, however, be understood that the following exposition is not a reproduction of the detailed studies elsewhere given, and in no wise claims to be a full development or establishment of the facts to be set forth.

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* The communication here referred to has been delayed by the illness of the author. TRANSLATOR.

SECTION II.—*The dioptric conditions on which the performance of the microscope depends.*

For the purpose of demonstrating the course of rays of light by which images of an object are formed in the microscope, a well-known diagram is usually employed, which shews, constructively, a reversed image produced by the objective and collected by the field lens of the ocular, which image is further enlarged and projected by the action of the eye-lens to the distance of clear vision in front of the observer's eye. And the discussion of each special condition, upon which the resulting total optical effect quantitative as well as qualitative depends, is based upon analysis of what takes place according to this diagram of construction. Such a scheme may perhaps suffice to give a general idea of the operation of the microscope; but if dioptric analysis be required for a more strict estimate and examination of the several factors concerned in the image-forming process, it must be carried out more completely, and extended in new directions.

IV. The course of the rays must be followed from a more general point of view. The same rays which, coming in homofocal pencils from each constituent point of the object, enter the microscope to form an image of that object, must also be regarded as homofocal rays coming from the several points of a plane situate outside the microscope (before or below it). This plane is, dioptrically interpreted, the outwardly projected aperture of the objective, and includes any object within the outlines marking the angle of aperture; in particular, the source of light serving for illumination of the object, *e.g.*, surface of mirror. Consequently, in addition to those images *of the object* which are thrown off successively by the lenses of the microscope, a series of *associated images of the aperture* are simultaneously thrown off, which together form an image of the outwardly projected plane of aperture. This latter (aperture image) is thus associated with the final virtual image of the object, and appears at the eyepoint, so called, above the ocular where it may be examined with a lens. But the image of the object, so far as it is produced by the objective alone, lies in or close to the upper focal plane of the objective, where also it may be seen by looking down the tube of the microscope with the naked eye. These two sets of images are interconnected by common relations, the determination of which affords a key to the solution of questions scarcely to be approached by any other means. All the characteristics of the *object images* hang together with certain characteristics of the *aperture images*, and *vice versa.* Those of the aperture image, in particular, afford the means of determining the limiting outlines of the pencils of rays by which images of the object are formed. On this again are based, theoretically, propositions of general application respecting the so called "penetrating power" of the microscope, and respecting the influence which diffraction of light passing in through the aperture of the objective exerts upon the microscopic picture; and above all, respecting the conditions which affect the brightness of the picture, and the *modus operandi* of the several methods of illumination, and the various appliances for this purpose. On the other hand, actual observation of these aperture images, conducted with suitable apparatus, affords additional means of studying the *object*, because in these aperture images the track of every ray which, coming from the object, enters the microscope in any direction whatever, will be seen. For instance, the bright parts of any "aperture image" (*e.g.*, the first one formed, after passing through the lens in the upper focal plane of the objective) indicates the several pencils which come from the object and form the image. Hence any change produced by the action of the substance of the object itself on these rays, especially any deflection of rays, will be at once recognised by some corresponding change of the aperture image. This fact will find manifold applications, and be further discussed in the following chapter.

The principle on which is founded the full development of the study of these aperture images leads to various results, depending for their full development upon a principle which constitutes at the same time a law of fruitful application throughout the whole theory of the microscope and which may be thus formularised.

When an objective is perfectly aplanatic for one of its focal planes, every ray proceeding from this focus strikes the plane of the conjugate focus at a point, whose lineal distance from the axis is equal to the sum of the equivalent focal length of the objective × the sum of the angle which that ray forms with the axis.

Now as this condition must be fulfilled in every correct instrument, both for the objective and for the whole optical part of the microscope, the formula above given establishes a relation of quantity between the *angle of aperture* of the microscope and the lineal diameter of the aperture images above the objective and ocular. Moreover, it is thus possible to determine, by micrometric measurement of the position in the upper focal plane of the objective which the track of any ray occupies, the direction which it took before entering the microscope. Consequently the aperture images formed above the objective, when examined with a suitable micrometer eyepiece, can be used for measurement of the divergence which the rays coming from the object undergo.

V. In the next place, we need a more characteristic exposition (than is afforded by the ordinary schematic diagram) of the essential optical functions which, in the case of images formed under larger angles, by rays having a *great* inclination to the axis (*i.e.*, wide angles of aperture), differ greatly from the abstraction by which theory represents the action of a set of lenses in forming an image. And such an exposition offers itself when we can define by axioms of general validity the mode in which an image is focussed and spread out on the focal plane of an optical system, and distinguish the *focussing function* and the *extension of image* over a surface as the two principal factors of the image-forming process, alike independent in their abstract idea, and distinct in actual specific function. Apart from the fact that no exhaustive analysis of a faulty image, nor any means of perfect correction are possible until such characteristic distinction can be laid down, we have no other means of determining the part taken by each constituent element of a compound system of lenses in the joint performance of the whole. The absence of any sure guide—in other words, the want of such adequate conception of the optical functions of objective and ocular respectively, as might bring into instructive contrast whatever essential differences exist between the functions of these two portions of the microscope, whilst at the same time that which is merely incidental and unimportant is eliminated—has been, and still is, the cause of serious defects which have hitherto attached to theories of the microscope, and also the occasion of certain mis-directions which have been taken in the endeavour to render it more perfect. When then we define the function of the objective to be, the production of a real image, and the function of the eye-piece, the amplification of this image,—such explanation, however true and serviceable to a certain degree, does not by any means reach the essential principle of action of the compound microscope. This is obvious at once when we consider that by such a definition the combination of objective and eye-piece is made only to indicate *magnifying power*, whereas on the contrary the remarkable superiority of compound over simple microscope consists in the *quality of its performance*, even with such moderate magnifying power as the simple microscope can reach without much difficulty. On the other hand, the proper signification of the principle of combination is indicated in this, that a characteristic division of work obtains in respect to the focussing function by which an image is formed, and the function by which that image is spread out over a much larger area, these functions being carried on in such wise that the specific *modus operandi* of the first belongs to the objective, that of the latter to the eye-piece. By the *objective* an image is formed and spread out in what is practically an almost perfect accordance with the laws by which images of infinitely small elements of a surface are formed. By the *eye-piece* a displacement of focus is effected; that is to say, a change of divergence of each separate pencil of light takes place till the divergence is almost imperceptible, and the pencils infinitely fine. On the other hand there must be taken into account the peculiar circumstance of altering divergence of pencils of large angular aperture after entering the objective; and that equally peculiar condition which obtains in the ocular of expanding superficies of image due to widely diverging rays. But it may be shown that the production of a fairly perfect picture, under the conditions of aperture angles and image-forming angles above described, cannot be effected in any optical apparatus otherwise than by such a distribution of specific focussing function, and specific act of amplification over different parts of the instrument; and, consequently, that the admitted advantages of the compound microscope arise from this combination of the several functions of "objective" and "ocular." It follows, however, from this, (so long at least as present principles of construction are applied) that the actual boundary-line between "objective" and "ocular" function is not to be sought where the image produced by the "objective" is presented to the "ocular," (at the field lens) but rather in the "objective" itself, where the rays which entered in a divergent direction are rendered, by repeated refractions, parallel, from which line (plane) they become by further refractions convergent on their course towards the ocular.

VI. Consistently with this result an analytical diagram of a more distinctive kind must be substituted for that in ordinary use whenever it is required to ascertain the quality of a microscopic image, by reference to the conditions which are really determinative, and which, moreover, may be advantageously applied as a basis for determining the quantitative relations of the optical action. According to this analysis the first step or act in the image-forming process consists, not in the production of a reversed image by the objective in front of, or within, the ocular, but rather in the production of a "virtual" image at endless distance with parallel rays (such as is seen when an object situate in the principal focus of any simple converging lens is observed by the eye placed behind it). The *second* act comprises the last refraction through the posterior surface of the objective, and the several refractions taking place in the ocular, (field lens and eye-piece) by which the image is re-formed at the distance of clear vision with diverging visual angles. The first act answers plainly to the function of an ordinary "magnifying glass;" while the second, taking all the changes comprised therein together, answers as obviously to the functions of the telescope (possessing only a small objective aperture) to which the virtual image formed by the first process serves as "object."*

This analysis of the collective action of a microscope system of lenses is fully confirmed by the circumstance that the site of the final refraction taking place in the objective, which gives to the now parallel ray a converging direction towards the ocular, is always to be found in the posterior focal plane of the objective. An imaginary lens separated at this place from the objective system, and possessing a focal length which answers to the length of the tube of the microscope, would represent the "object glass" of a telescope whose effective (visual) angular magnifying power might be computed according to rule by estimating the power of the ocular and the length of tube. The equivalent focal length of the front portion of the objective, here supposed to be performing the work of a simple magnifying glass, would remain as before (the same as) that of the objective itself, and would give by known rule the means of determining the visual angle under which the object before the microscope must appear as virtual image, formed by parallel rays at endless distances. This interlocking of objective and ocular functions—presenting the combined effect of a magnifying glass and that of a telescope—must be laid down as the most general and correct characteristic of the principle upon which the com-

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* In illustration of this mode of analysing the action of the microscope, it may be worth while to point to the fact that when a properly corrected lens (of any chosen focal length) is centred in front of a telescope, the action of the last becames that of a microscope.

pound microscope of the present day is constructed; and on this basis, as will be shewn in the sequel, many questions bearing with equal importance on the theory of the microscope and on its rational construction, find their solution—such, for instance, as respect the exact seat of various sources of error, the means of correcting them, the limits of perfection which may be possibly assigned under given conditions, and the influence separately exerted on the quality and sum of the total effect by the several factors; focal length of objective, length of tube, and strength of ocular.

VII. In the foregoing remarks the chief points have been indicated from which an exhaustive theory of the microscope must be set forth, From them may be gathered a theory of aberrations, or faulty formation of images, sound and strong enough to master the difficulties which the application of exceptionally large angles of aperture to microscope objectives has occasioned.

It appears that these faults of image formation are separable into two distinct classes, one comprising faults of the focussing act (aberrations in the strictest sense), the other comprising faults of the amplifying function (extension of image over a larger superficies), which latter have not hitherto been considered. To the first class belong those spherical and chromatic aberrations commonly studied; in the second class must be placed a series of peculiar deviations of rays of light from their normal course, which arise from the circumstance that the separate rays of a homofocal beam occupying the aperture of the lens yield unequally magnified images, according as their inclination to the axis varies, and according also to the unequal refrangibility of the different colours—an inequality which obtains just as much whether the several partial images are compared with each other, or whether within the area of each image different positions in the field of vision are compared. From these deviations, which Professor Abbe terms *anomalies of amplification* rather than *aberrations*, arises that well-known indistinctness of image outside the central portion of the field, and in particular that peculiar kind of chromatic fault which, although it has nothing to do with the chromasy due to focal differences, has been hitherto interpreted as an indication of it.

This class of anomalies affects exclusively the constitution of the image outside the centre of the field. The perfection with which the rays unite in the central region, and therewith the maximum capacity of performance, depends on the contrary entirely on the real aberration spherical and chromatic, as commonly understood. A closer analysis of these yields the following results.

(i.) Chromatic aberrations, as they shew themselves where a large angular aperture is used, do not depend alone on those differences of focus which affect the image-forming beams as a whole (in accordance with the phenomena of dispersion of colours and their un-uniform course through crown or flint glass); but also quite as much in an unavoidable inequality of coincidence of colours of variously inclined pencils of rays within the angle of aperture, which manifests itself in this, that an objective which is perfectly achromatic when direct illumination is used must be more or less *over* corrected for use with oblique illumination. Although the first mentioned ordinary form of colour dispersion (primary and secondary) may be entirely removed or rendered scarcely noticeable, the last named source of chromatism cannot be counteracted or removed by any known material or any known technical treatment. Its influence is such, moreover, as to set limits to the attainment of perfect action (at least in objectives of middle and moderately high power) before their action would be affected by other unavoidable sources of error. According to Professor Abbe's experiences the actual performance of objectives whose focus ranges from 6 mm to 3 mm ($\frac{1}{4}$th to $\frac{1}{8}$th) falls in consequence of this defect far below what might be attained so far as the possibility of correcting spherical aberration by appropriate technical means is concerned.

(ii.) Spherical aberration on a stricter examination of its causes resolves itself into a series of independent elements which as they increase in number, follow, with the increasing inclination of the rays towards the axis, a more and more unequal course. An absolute effacement is only possible theoretically for the two first members of the series. As soon as the angular aperture exceeds a small number of degrees, the counteraction of spherical aberration can be effected in no other manner than by compensating the irremoveable errors of the higher elements through intentionally introduced residual aberrations of the lower ones. The accumulation of unavoidable deficits which this method of compensation necessarily leaves unremedied in consequence of the want of uniformity in the course of the several elements, compels a limitation of the angle of aperture, otherwise this deficit will affect the microscopic image injuriously. For angles of aperture exceeding 60° and *a fortiori* for the very large angles of modern objectives, the theoretically indispensable pre-supposition of an adequate compensation is found in the well-known type of construction where a plain nearly hemispherical front lens is combined with a strongly *over* corrected system of lenses. The discovery of this mode of construction must be looked upon as the basis of every improvement which has been introduced since. For a system of lenses made to use in air, the limit of serviceable aperture proves to be from 105° to 110°, beyond which it is not possible to counteract sufficiently the spherical aberration, except by lessening the focal distance of front lens from the object to a degree which makes it practically useless. The application of the immersion principle renders it possible on the contrary to overcome spherical aberration, where even the *maximum* angular aperture is used, by proper adaptation of the altered relations thus introduced. It is in this power of using very large angles of aperture without proportional detriment to the correction of spherical aberration, and also in avoiding the loss of light caused in the dry system by reflection from the surface of the front lens, that the real advantage of the immersion plan lies. It will indeed be seen from what follows, that these two facts fully explain the undoubted superiority of the immersion lens.

Mathematical analysis further shews us in what form spherical aberration will manifest itself when from faulty construction a noticeable residual error appears. However irregular the actual course of the rays may be in any particular case in the neighbourhood of the plane where they should coincide, (according to construction) this course may be always so altered by mere change of a lens-distance in the system (as is affected for example by correcting for glass cover) that the central and peripheral zones of the objective may work together correctly while the intermediate zone remains for the time more or less *over* corrected. At the same time, it is evident that so typical a difference of correction, where it once exists, cannot be removed, or even diminished, by any external means; for since it lies in the relations of curvature and refractive power of the front lenses of the objective, every appliance by which the amending of such aberration has been attempted—whether by correcting lenses placed above the objective or by particular construction of ocular —will produce, under the most favourable circumstances, no better result than what is already effected by changing the distance of the front lens of the objective from those behind it. They simply permit the existing residual aberration to be transferred—shifted backwards or forward between the centre and outside border of the aperture—and by this means to keep, for a time, some particular zone of the objective more or less free from aberration, *at the cost of the rest!* Arrangements like the "aplanatic searcher," invented by Dr. R. Pigott, originate in a misconception of the true state of the matter. They rest upon a conception of spherical aberration, which, as it leaves place only for a single alternative, *over or under corrected*, is, together with the whole theory of aplanatic foci built upon it, utterly without meaning or object, in the case of the powerful microscopes of the present day.

VIII. An analysis of the conditions which belong to a perfect construction finds its fit conclusion in applying it to investigate the influences severally exercised by the different parts on the general effect of the whole. And here, before all things, it becomes obvious that the factors on which correctness of image in the centre of the field, and consequently the maximum of good performance depend, namely, chromatic and spherical aberration (in the stricter sense, as before explained), pertain to the functions of the *objective* alone, upon which no influence of the eye-piece, however constructed, can produce any marked effect. And further, that any errors in definition of the image to which the ocular might in part contribute, do not diminish the attainable perfection of the whole, except in so far as there remain unavoidable residual aberrations due to the deficiency of focussing function of the objective (in the special sense already described). Gross faults of construction excepted, the ocular, however simple its construction, may be considered practically free from error in comparison with the anomalies of colour and amplification which arise from faulty action of the objective in respect to its focussing function. Hence it follows that the maximum efficiency of performance depends entirely on the objective, and that no imaginable improvement in the ocular can influence it in any degree. Also that the conditions under which the ocular is made to act—as, for instance, in obtaining greater amplification by increased length of tube or strength of ocular—are entirely indifferent so long as such arrangements are kept within practical bounds; and therefore the excellence of performance will not be lessened provided the objective used be chosen to suit the assumed conditions. Arguments advanced in England (Pigott) in favour of a long tube, as recently in France, by Prasmowscki, in favour of a short tube, are equally untenable in theory; and the supposed differences of effect prove to have no real existence when examined under conditions which are truly comparable. In like manner the reports of extraordinary performance of this or that ocular, supposed to be due to its special construction, prove, when tested by theory and *accurate* experiment, to be illusory in so far as any real increase of optical power is in question, and not merely some advantage of secondary and only collateral importance, such as increased field, &c., &c. In view of these results, special significance must be attached to the analytical limit here assigned to the respective functions of objective and ocular, and to the constructive diagram founded thereon. Every fault of the image-forming process which influences in a general sense the delineation, finds its full expression at once in the quality of the virtual image of the object which is produced by the front lenses of the objective acting as a simple magnifying lens. In contrast with this the whole ocular apparatus, consisting of tube and lenses, acting as a telescope, merely plays the part of an indifferent magnifying mechanism, which serves simply to spread out before the eye at the necessary visual angle the image formed by the objective without adding to, or taking anything from the quality of its contents. These contents, so far as *possible* details are concerned, will depend upon the angular magnitude of the dispersion circles which are formed in the objective virtual image where there ought to be sharply defined points only, and which are the result of faults of the image-forming process inherent in the construction of the objective. Taking their intervention in the final effect into account, there will be found for every objective a particular angular amplification obtainable at will by means of length of tube and strength of ocular, which must exactly suffice to enable any eye, possessing normal capacity of vision, to recognize perfectly all the details that can possibly be delineated in the virtual image formed by the objective. And this, which may be termed "necessary *angular* amplification," may be looked upon as the measure of the relative perfection of the objective. From it may be determined, by easily deducible rules, with the help of its focal length, the necessary *linear* amplification, *i.e.*, the numerically estimated amount of magnification at which the capacity of performance of the objective is exhausted. This is then, the lowest magnifying power, with which every detail will be seen that *can* be delineated by it, according to its measure of optical power. A further amplification may still be serviceable, as the detail will be made out more clearly and with greater ease, but it will in no wise raise the optical power of that particular objective.

Assuming equal relative perfection of construction, the angular magnitude of the dispersion circles of the objective virtual image of lens-systems possessing widely different focal lengths, must be the same; therefore the absolute magnitude of the smallest particles which can be separately delineated must constitute the same fraction of the focal length. From this it follows, on the one hand, that the necessary *angular* amplification for such objectives is equal, and its amount represents accordingly the measure of relative perfection; on the other hand, that the necessary *linear* amplification, and therewith the absolute optical power, must—assuming always equal relative perfection of construction—increase in the same proportion as that in which the focal length diminishes.

In the practical application of the definitions here propounded, it must not be forgotten that the dispersive circles of the objective virtual image, caused by defective technical execution and residual aberration, never attain, when the higher power objectives are used, so serious an import as they would in the case of dispersion produced in large pencils, filling the whole aperture. As a matter of fact, as soon as the angular aperture becomes considerable, a small portion of it only is occupied at one and the same time by image-forming pencils, and the aberrations are, therefore, proportional to the amount of surface occupied. And since, as we learn from the study of "aperture-images," the area actively occupied with image-forming pencils is constantly changing place and size, according to the mode of illumination and the structure of the preparation under view, it follows that any determination of the "necessary magnifying power" which shall be valid in all cases is impossible.* Nevertheless, the

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* Neither does the method recommended by Harting of determining the limits of resolving power through observation of minute images, such as are obtained by means of small air bubbles, &c., ensure the determination

theoretical points of view here indicated are quite applicable to an approximative estimate of the performance which may be expected from the instruments of the present day; and their enunciation may well serve to remove those illusions to which many writers on the microscope seem disposed to give themselves up. Theoretical study of the aberrations of the image-forming rays, and practical experience involving the application of methods to be hereinafter described, and the careful testing of a considerable number of objectives of recent date from the best workshops on both sides of the channel, have led Professor Abbe to the conclusion that the numerical value of "necessary amplification" yet arrived at or attainable, at present, is altogether much lower than might be supposed from the liberal way in which microscopists deal with thousands and tens of thousands. According to his experience, the optical power (capacity) of the most perfect objectives, the usual forms of illumination being assumed, is exhausted with an eight-fold *angular* amplification, so that every detail that can be possibly delineated by an objective in its "virtual" image is certainly accessible to any eye possessing normal vision, when the tube and ocular, taken together, represent a telescopic magnifying power of eight times. Even this performance is only reached in the case of low and middle

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of the optical power of the microscope in any practically realisable way, or one capable of general application; for apart from the fact that the course of effective rays in this case differs widely from all the formulæ which apply in the ordinary modes of using the microscope (at all events, with the higher objectives), it may be demonstrated, as will be seen in the next following chapter, that the resolution of details in such air-bubble images by no means depends upon the dioptric action of the objective alone, but quite as much, or more, upon special and entirely independent influences, extraneous to the action of the microscope. The results of Harting's method shew, in point of fact, only the limits of a resolving power which is unconnected with dioptric perfection of the objective, just as in the case of the observations of Roberts' test-plate, or of the Diatoms, though under somewhat altered conditions of illumination.

power objectives; for when the focal length is less than $\frac{1}{8}$th inch, the relative perfection of construction perceptibly fails, on account of the rapidly accumulating technical difficulties, and there certainly does not exist an objective of $\frac{1}{25}$ inch focus whose optical capacity exceeds a five-fold *angular* amplification. It is easy, accordingly, from this, to calculate what figures indicate the *necessary linear* amplification with objectives of different focal lengths (about $\frac{500}{1}$ for $\frac{1}{6}$ inch, $\frac{1200}{1}$ for $\frac{1}{25}$ inch); and, further, what extreme amount of magnifying power may be accepted as really serviceable when we take into consideration that the mere extension of an image by large visual angles of formation, without any corresponding increase of optical capacity (especially where the amplification is already so great and proportionately so weakly illuminated), must tend to injure, rather than to assist, the clearness of visible impression.

From all this may be gathered how utterly futile any efforts to obtain disproportionately high amplifications by means of specially constructed eyepieces must prove; and, as regards any expectation of exalting the performance of the instrument by further shortening of the focal length of the objective, there stands in the way one objection, which, apart from all others, in the present state of our knowledge, is absolute and insuperable—namely, that the imperfections resulting from residual aberrations and defective technical manipulation increase with every addition of magnifying power, through the effect of diffraction occasioned by the minute surface of very high power lenses. This form of diffraction, likewise, turns the image of each point in an object into a dispersive circle of greater or less diameter; but the resulting diminution of optical capacity, while scarcely noticeable in objectives of moderate power, compared with the effect of residual aberrations, becomes very serious with the higher powers. It may be shewn, as a general rule, that the influence of this source of error, which has nothing to do with the optical power of the microscope (or of the telescope), depends alone upon the magnitude of the final aperture-image seen by the eye above the eyepiece, and is inversely proportional to this magnitude. It takes, in every particular, the same form as when the microscope image, supposing it to be still free from this diffractive effect, were observed through a small hole pierced in a diaphragm of the same size as the diameter of that aperture image. This diameter, however, depends on the angle of aperture of the microscope and its collective focal length; hence, also, on its collective amplification, and may be calculated on the formula given in (¶ iv.) Assuming the magnitude of angle of aperture 180° in air, which cannot be exceeded beyond a few degrees, even by immersion systems, we find, *e.g.*, for an amplification of 1000, the diameter$=\frac{1}{50}$ inch, and for amplification of $5000=\frac{1}{250}$ inch, without reference to the mode in which the amplification is obtained (through objective and ocular). And if we would know what conditions are involved in such amplifications—as, for instance, 5000 fold, we have only to make a puncture of $\frac{1}{250}$ inch diameter with a needle in a card or piece of tinfoil, and through this opening to look at some brightly illuminated object, which has well defined edges (*e.g.*, a candle flame), and we shall have before our eye of what must be the appearance of the outlines of a microscopic object magnified 5000 times, even if the microscope itself were absolutely perfect, the diffractive effect excepted. *

Taking all these circumstances into consideration, it must be concluded that no material exaltation of the absolute optical power (capacity) of the microscope, beyond what is attainable at present with objectives of $\frac{1}{25}$ inch focal length, is to be expected in the future, either by shortening of focus or by further improvement of construction. And as there exists at this moment no microscope whose *serviceable* magnifying power reaches even to 4000 (if any serious sense of the term "*serviceable*" be intended), so will there be none in the future. On the contrary, the facts just stated shew that amplifications of less than half 4000—such

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* Due to smallness of aperture of a minute lens, and to be carefuly distinguished from the diffractions which is caused by the *structure* of objects.

as are readily obtained with objectives of $\frac{1}{25}$ inch, and seem really *serviceable*—are nevertheless not available in practice, because various other conditions besides the perfection of the image-forming function cannot be fulfilled. The final inference from these data is that improvement of the microscope should no longer be sought for by aiming at still higher magnifying power and amplification, but rather at a more correct performance of the middle and moderately high powers. It will be a real advance of the optician's art, and of infinite service to the scientific use of the microscope, when we succeed in accomplishing with objectives of $\frac{1}{6}$th and $\frac{1}{8}$th what is now only attained with much higher powers. Such an aim is within the range of what is possible; other aims will only be directed at castles in the air!

X. In the account of Professor Abbe's researches, to be communicated in the *Jena Journal*,* to which reference has been before made, new and exact methods are given by which every determinable point in the construction of the microscope *e.g*, focal length of each lens, angle of aperture, character and limits of objective and ocular functions may be empirically ascertained.; and, in addition to this, a mode of procedure is described which renders it possible, with very simple means, to examine in instruments already made, every fault of definition of image indicated by theory, and thus to determine their relative excellence. The methods commonly recommended for testing the state of spherical and chromatic correction of the objective are not adequate to the actual requirements of the case, and quite fail to explain the true character of the aberrations; for the effect of these, as rendered visible by such methods, is not due to elementary sources, but to combined results of many different causes; and since each separate source of error plays a very unequal part in the total result, any judgment founded on this alone, may, according to circumstances,

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* While this is passing through the press, I learn that the proposed communication is deferred, and that a separate treatise on the subject will be published by the author.—H.E.F.

entirely miss the mark. A trustworthy estimate of a well constructed and correctly performing objective—if based at all upon ascertained condition of its delineating power—can only be formed by analysing every visible aberration in its separate elements, and by tracing out singly each one of the whole sources of error in operation.

The principle upon which the mode of proceeding to which reference has been made above, may be here generally indicated.

As test object, is used a preparation which presents only sharply-outlined black and white lines alternating with each other, and *lying in the same plane*, so that no deviation can occur in the course of the rays transmitted through it. A preparation of this kind, sufficiently perfect for all practical purposes, may be made by ruling groups of lines (coarse and fine), with the aid of a dividing machine, on the metallic film of silver or gold fixed by known methods on glass, and having no greater thickness than a fractional part of a mikro-milimetre (1 mikro-mm. $= \frac{1}{25000}$ inch). Covering glasses of various thicknesses (accurately measured) are ruled on their under surfaces with lines $\frac{1}{250}$ to $\frac{1}{1250}$ to the inch, and cemented on a glass slide with balsam, one beside the other. A preparation of this kind serves for the highest as well as lowest powers. The illumination must be such that light may be reflected simultaneously from several sides upon the object, and means provided for regulating at will the course of any pencil entering within the angle of aperture of the objective to be tested.

The testing process has for its aim to bring under view the co-operation of every zone of the aperture, whether central or peripheral, and yet, at the same time, to be able to distinguish and recognise the images which each zone delivers separately. For this purpore the illumination is so regulated that every zone of the aperture shall be represented in the image formed at the upper focal plane by tracks of the entering pencils of light, yet so that for each zone a small streak only of light be let in, and that the tracks be kept as widely apart from each other as possible. According to the amount of angular aperture, two or three isolated pencils may be correlated. These would be so arranged that, supposing the surface of the front lens of objective measured $\frac{1}{4}$ inch diameter, and two pencils were to be compared, then, in the first case, *one* track (a nearly circular pencil) would reach from the centre of the field to about $\frac{1}{16}$ inch from it, the *other* track, let fall on the *opposite side of the axis*, would reach the outside edge of the the aperture occupying a space $\frac{1}{16}$ inch distant from the centre to the edge. In the second case, (where three finer pencils are employed) the first track should occupy the zone from centre to a distance of $\frac{1}{25}$th inch from the centre, the second track a zone on the opposite side between $\frac{1}{25}$th and $\frac{1}{12}$th inch from the centre, and the third track, the peripheral zone, on the same side as the first track.

This arrangement places the pencils of light in their most sensitive position, and exposes most vividly any existing defect in correction, since the course of the rays is such that the pencils meet in the focal plane of the image at the widest possible angle. As many zones or portions of the objective as are put in operation by the passage of pencils of rays so many distinct images will there be perceived of the group of lines in the prepared object which occupies the field. If an objective be absolutely perfect, all these images should blend *with one setting of focus* into a single, clear, colorless picture. Such a fusion of images into one is, however, prevented by faults of the image-forming process, which, so far as they arise from spherical aberration, do not allow this coincidence of several images from different parts of the field to take place at the same time; and so far as they arise from dispersion of color, produce colored fringes on the edges bordering the dark and light lines of the object and the edges of each separate image, as also of the corresponding coincident images in other parts of the field.

A test image of this kind at once lays bare in all particulars the whole state of correction of the microscope. With the aid which theory offers to the diagnosis of the various aberrations, a comparison of the colored borders of the separate partial images, and an examination of their lateral separation and their differences of level, as well in the middle as in the peripheral zones of the entire field, suffice for an accurate definition of the nature and amount of the several errors of correction, each of them appearing in its own primary form. Therewith we also see that which arises from aberrations properly so called (faults of the focussing function) clearly separated from such imperfections or anomalies, which spring from mere differences of amplification between unequally inclined and unequally refracted rays. And, moreover, we can eliminate completely, by a simple manipulation, all influence of the ocular on the quality of the image outside the axis.*

Assuming the theoretical knowledge and practical experience necessary to carry out such an enquiry properly, and to estimate its results correctly, the mode of procedure above described affords so exhaustive an analysis of the qualities of an objective, that when, in addition, its focal length and angle of aperture are ascertained, its whole capacity of performance may be determined beforehand. For the ordinary requirements of the microscopist, a direct test by means of some natural object will be always preferred; but the occasional application of this method will yield useful data upon which a right judgment may be formed of the expectation which at present may or may not be entertained respecting the quality of the microscope. Whoever has once examined in this manner even good objectives which have proved to be excellent in practice, will be as little disposed to accept childish assertions of their perfectness as to advance on his part absurd pretensions which no one has yet made good.

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* In proof of these statements may be mentioned that by this method, in accordance with theory of dispersion of color, (which is actively going on in every part of the field outside its axis, where objectives of large angular aperture are used) no less than five separate elements are recognized, which, on account of their very unequal practical significance, must be strictly distinguished from each other.

SECTION III.—*The physical conditions under which images of minute structure are formed.*

XIII. That the performance of the microscope does not always depend solely on the geometrical perfection of the image, but also, in addition to this, in certain classes of objects, upon amount of angular aperture, is a fact long recognised, and one which has greatly influenced the construction of the microscope in recent times. The exact significance of this fact has nevertheless remained just as problematical as the exact nature of that especial quality which has, in connection with it, been attributed to the microscope ("resolving" or discriminating power—penetration). It remained, namely, a question, What value might be assigned to the quality thus related with angular aperture in the ordinary scientific application of the instrument, and does its significance extend any further than to certain particular cases in which shade effects were supposed to be produced by oblique illumination. ?

In the endeavour to establish a theoretical basis for the construction of the microscope, it was a matter of the first importance to define the exact function of angular aperture in the ordinary normal performance of the microscope, lest I should, in following a mere tradition, fall into a misdirection of my labours towards aims of very problematical worth. A definitive settlement of the principal points in question has been reached, as I believe, in the results now communicated, except in so far as new facts brought to light by these researches suggest further problems of a different kind.

As, then, it is important before all thing to ascertain more exactly than has been hitherto set forth in micrographic literature the actual facts respecting the operation and effect of angular aperture, I endeavoured to determine first by experiment in what cases a distinct advantage resulted from larger angular aperture, and in what cases no such advantage could be perceived, all other differences which might possibly influence the operation being most carefully eliminated. For this purpose a series of objectives, differing widely in focal length and angular aperture, were constructed with the greatest accuracy, according to my calculations, and their accuracy specially tested, so as to afford a certainty of correctness in comparing the observations made with them. The test objects employed included prepared insect scales of various kinds, diatom valves, striped muscle fibre, diamond-ruled lines on glass, groups of lines on silvered glass, fine and coarse powdered substances, and, besides these, the minute optical images of natural objects (lattice bars—wire-net) obtained by means of air bubbles, or, preferably, by objectives of short focus, fitted to the stage of the microscope.

XIV. These experiments yielded the following results :—

(i.) So long as the angle of aperture remains within such limits that no noticeable diminution of sharpness of image results from its diffraction-effect, no sensible improvement in the delineation of the outlines (that is to say, of the confines between unequally transparent parts) of the object takes place, provided these parts are not of less size than $\frac{1}{2500}$ inch.

(ii.) On the other hand, the difference is wholly in favour of the larger aperture for every object which yields details minuter than the limits above given ; and this is quite irrespective of the question whether such details are due to unevenness of surface or to unequal transparency in an infinitely thin layer, or whether the detail takes the form of striation, granulation, trelliswork, or images of natural objects' reflected from bubbles or produced by refraction of lenses.

(iii.) The smaller the linear dimension of such details so much the larger must be the angle of aperture of the objective, if they are to be made out with any definite kind of illumination, *e.g.*, whether purely central or very oblique : and this is irrespective of the more or less marked character of the delineation and of the focal length and necessary amplifying power of the objective.

(iv.) When the detail in the real object appears in the form of striation, groups of lines, &c., a given angular aperture always reaches much finer details with oblique than direct illuminations, and this is irrespective of the circumstance that the constitution of the object admits or entirely excludes the possibility of shade effects.

(v.) A structure of the supposed kind, which is not revealed by an objective used with direct illumination will not be rendered visible by inclining the *object itself* at any angle to the axis of the microscope, even when, lying at right angles with the axis, it is perfectly resolved by oblique illuminations. Resolution, however, follows at once when the incident light is directed perpendicularly to the plane of the object, as it lies inclined to the axis. Hence the increased effect of oblique illumination depends solely on the inclination of the rays towards the axis of the instrument, and *not* upon the oblique incidence of light on the object.*

The facts here brought forward shew, on the one hand, the reality of a special optical quality, directly related with *angular aperture* of the objective, yet independent of any special perfection or amplifying power possessed by it, and shew it to be a "resolving" power or capacity of separating minute detail, conformably with the literal sense of the term employed. On the other hand, they shew unequivocally that the delineation of images of minute details of structure must take place under conditions essentially different from those under which the contour outlines of larger parts are formed. In all cases where a "resolving" power of this kind—that is to say, a direct influence of angular aperture, whether positive or negative—is in operation, the dioptric reunion of rays proceeding from the several points of the object in the focal plane of the image is most certainly not to be accounted an adequate explanation of the images of such details of an object, for on such a supposition the differences experimentally ascertained and above described would remain absolutely

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* *Vide*, Wenham in monthly *Microscopic Journal*, April 1, "On a method of obtaining oblique vision of surface of structure, &c." The optical principle enunciated by Mr. Wenham is totally irreconciliable with Prof. Abbe's theory and experimental investigations.

inexplicable. The result, then, of this preliminary study is to give the following form to the enquiry—namely, to find out the special causes *outside* the microscope which co-operate in the formation of images of small structural details, and then to determine individually the mode and manner of their intervention in the dioptric process. Each of these requirements has been fulfilled theoretically and experimentally as far as needed for our present purposes.

XV. The undulation theory of light demonstrates in the phenomena of diffraction or inflection a characteristic change which material particles, according to their minuteness, effect in transmitted (eventually also in reflected) rays of light. This change consists, generally, in the breaking up of an incident ray into a group of rays with increased angular dispersion within the range of which, periodic maxima and minima of intensity *(i.e.*, alternation of dark and light) occur. For the particular cases of regular lamination, striation, rows of points, and the like, mathematical theory offers a full definition of the phenomenon, which consists in this, that from the rectilinear incident ray there is deflected on each side of it a series of isolated rays, which diverge with regulated angular distances from each other. But these angular distances are for each colour proportional to its wave length, and increase, therefore, in size from violet to red, and are also inversely proportioned to the distances between the particles in the object which cause diffraction. When a microscopic preparation possessing the structural peculiarity under consideration is illuminated by a cone of rays thrown by the mirror of the microscope upon it, the light does not enter the objective in the same direct line which it held in its course from the mirror towards the object, because the structure of the object causes a number of deflected and color dispersing rays to be separated from the rectilinear rays; and these deflected rays form larger or smaller angles with the lines of direction of the unchanged rays according to the greater or less minuteness of structure. This class of objects transmit therefore point for point *several* isolated pencils to the objective, the number and disposition of which within a defined angular space depends on the position of the mirror and the structure of the preparation.

This effect, which is not only such as might be theoretically predicted, but also capable of exact calculation, may be readily observed by examining the aperture images which accompany the images of the object as before explained. Having placed some object of the kind in question under the microscope and got its detail in focus, the ocular must then be removed and the image of the object in the open tube may be viewed with the naked eye, or a suitably arranged microscope of weak power ($\frac{10}{1}$ to $\frac{20}{1}$) which can be let down in the tube to the upper focal plane of the objective. The image of the mirror or whatever illuminating surface may be used will be seen as it is formed by the undiffracted rays, and surrounded by a greater or less number of secondary images in the form of impure colored spectra, whose sequence of colors reckoning from the primary image, is always from blue to red. Objects consisting of several systems of lines which cross each other shew not only a series of diffraction images of each group in the direction of their perpendicular, but also, as theory would require, other additional series in the angles between the perpendicular groups. Insect scales and diatom valves exhibit these phenomena in the greatest variety. The coarse specimens admit of examination with low powers of small angular aperture; the finer, from pleurosigma angm. upwards, require large angular aperture even to get into the aperture the diffraction images lying nearest to the primary image of the mirror. A weak immersion lens is the best for such observations.

XVI. This method of direct observation of pencils of light coming direct from the object enables us, at the same time, to determine by experiment what part is played by diffractive phenomena in forming the image of the structure in question. A suitable test object being placed in focus, and the light being suitably regulated by diaphragms placed immediately *above* the objective, as closely as possible to its upper focal plane, for the purpose of excluding at will one or another portion of the groups of rays exhibiting diffractive effects, the image of the preparation, as formed by those rays only which were not so shut off, could be readily observed with the ordinary ocular. The immediate result of experiments carried out in this manner was as follows, it being first premised that every determinative trial was made with very correct low power objectives ($1\frac{1}{4}$ to $\frac{1}{4}$ inch) and corresponding weak amplification:—Higher powers, an immersion lens of $\frac{1}{8}$ inch in particular being used only to control the results obtained already with coarse objects by experiments on the finer diatoms. The preparations for all decisive trials were of such a kind that their structure was accurately known before hand, various granules of finely powdered substances, system of lines scratched in glass, whose linear distance varied from $\frac{1}{800}$ inch to $\frac{1}{1200}$ inch; also similar groups of lines ruled on silvered glass, the silver coating being immeasurably thin; groups of lines crossing each other without any difference of level were obtained by laying upon each other two glasses, the surface in contact being separately ruled.

The facts thus ascertained are—

(i.) When *all* light separated from the incident rays by diffraction was completely shut off by the diaphragm, so that the image of the preparation was formed solely by the remaining undiffracted rays, the sharpness of outline at the confines of the unequally transparent parts of the field was *not* affected, provided the opening of the diaphragm remained sufficiently large, so that no diffraction arising from the reduction of its opening should occasion any visible lowering of the "necessary amplification;" nor will the clear recognition of separate structural particles be sensibly hindered, provided that not more than 30 to 50 of such particles are found in $\frac{1}{25}$ inch.* But the more this number is exceeded so much the more of detail disappears, so that when the fineness of

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* The definition of number is here uncertain, because the exclusion of diffracted rays, whose diffraction is slight, can only be obtained by using a diaphragm pierced with small openings.

detail reaches 100 parts to the milimetre (that is when their interspace is only $\frac{1}{2500}$ inch) nothing remains visible except a homogenous surface whatever magnifying power be used, or whatever mode of illuminating (direct or oblique.) Even a couple of lines ruled on a glass will, under the circumstances above stated, be not otherwise distinguishable than as one broader line with sharp outlines. With the most powerful immersion lens nothing at all can be seen of the markings of Pleurosigma angm., and even the coarse lines of Hipparchia Janeira remain unrecognisable with a power of 200. In the case of granular objects and other irregularly shaped particles, diffracted light cannot be completely separated from undiffracted light, and accordingly there is no absolute disappearance of all the particles; but such indefiniteness of image ensues that the finer particles of the preparation fuse into a homogenous gray cloud.

(ii.) When all light is shut off, excepting a single pencil of diffracted rays, a *positive* image of the particles in the object which caused the diffraction is formed, and appears more or less brightly on the dark field, but without any detail. Ruled lines appear as uniformly clear flat stripes on a dark ground.

(iii.) But when not less than *two* separate pencils are admitted the image always shews sharply defined detail, whether it appears in the form of system of lines, (one or more sets) or of separate fields; nor does it matter whether undiffracted light passes in with the incident cones or not: that is to say, whether the image appears on a bright or a dark field. If fresh pencils be set in operation fresh details appear, but always different, according to the degree of minuteness, or to the nature of the markings; *and this detail is not necessarily conformable either with that of the image as seen by ordinary illumination, or with the real structure of the object as known or ascertained in other ways.* In respect to this last point the following particulars are noteworthy.

(iv.) A simple series of lines will be always imaged as such when two or more illuminating pencils are set in operation, but the lines will appear doubly or trebly fine when, instead of the pencils being consecutive in order of position, one, two or more intervening pencils are passed over. Thus a group of two lines only in the object appears as if composed of three or four separated sets. The phantom lines thus created cannot be distinguished by help of any magnification from the normal image of actual lines of double or treble fineness, either in respect to sharpness of definition, or constancy of appearance as may be shewn by a conclusive experiment, in which namely, the falsely doubled image appears side by side with the image of an object actually ruled with lines of double fineness.

(v.) When two pieces of simple lattice cross each other in the same plane at any selected angle, the systems may, by suitable regulation of the admitted pencil of light, be rendered visible together, or separately, and further by varying the form of illumination, numerous fresh systems of lines and variously figured fields which do not exist at all as such in the object may be made to appear with equal sharpness of delineation. These new systems of lines always correspond in position and distance from each other with the possible forms in which the points of intersection of the real lines of the object may arrange themselves in equi-distant series.

Thus, for instance, a rectilineal net or lattice work shews two secondary sets of lines in the direction of the diagonals, the network of the latter appearing smaller than the actual net as $1:\sqrt{2}$. Also four more groups, but shewing more faintly and smaller still in the proportion of $1:\sqrt{5}$, each of which is inclined at an angle of about 27° to the direction of one of the real networks. With a network crossing at an angle of 60°, there appears, besides several smaller systems of lines, a third set marked just as strongly as the real net-work of the object, and with equal distance between the lines, inclined also 60° to the others; and when the three sets are seen together there will be seen perfectly sharply defined six-sided spaces (fields) of the kind observed on pleurosigma angm., instead of the rhombic fields. It may be added that all the appearances unconformable with the structure of known objects which are here described were observed with exactly the same focussing under which the normal image appeared well defined, and that they occurred under various combinations of objectives and oculars with regular constancy whenever the illumination was regulated in the same way. The influence of the diffraction, which might be caused by the diaphragm above the objective, was eliminated by means of experiments made for the purpose of control.

The partial exclusion of pencils of light entering from the object, (a manipulation purposely arranged in the experiments above described) happens unintentionally and unavoidably in the ordinary use of the microscope when observing any very minute microscopic structures; for when their linear dimensions fall below those of the lengths of the waves* of light, even the widest angled objective cannot take in more than a small part of the numerous groups of diffracted pencils at one time. This portion will be, however, constantly varying according as the angular aperture employed is larger or smaller, the direction of illuminating rays being unchanged; or according as the illumination is changed in direction, the angular aperture remaining the same. On this fact rests every modification which the images of minute structures undergo with altered angle of aperture or different incidence of light. The constant increase of *resolving* power resulting from oblique illumination, (in other words, the addition of fresh details) and the greater prominence of what was before visible with central illumination, is in every instance solely produced either by the entrance of diffracted rays into the larger aperture (with oblique illumination), which would otherwise not have entered into the objective on account of their greater divergence, or because diffraction-pencils which were but imperfectly

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* The wave length of Red = 0.76 micro-milimeters, (signified by the Greek letter μ;) that of Blue = 0.43 μ. For comparison, the distance between the lines of certain test objects may be here given. The longitudinal lines of Hipparchia J. = 2 m, the transverse markings = 0.7 μ; Pleurosigma augm., 0.48 μ; Surirella gemma, 0.3 μ; Frustulia saxonica, 0.25 μ.

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taken up when direct illumination was used now enter more completely and work with greater effect, whilst the direct rays are relatively less operative. Apart, however, from this, there frequently occur, during ordinary observations, such accidental moments of oblique illumination as may produce the effects described in paragraph v.; consequently in every object which presents two sets of striæ fairly homogeneous with each other several additional sets may, by a change in the incidence of light, be brought into view and become visible in different directions, provided the angular aperture of the objective employed has a suitable relation to the fineness of striation, as clearly appears in the case of various Diatoms. Even the forms of illumination which produce effects (such as are described in paragraph 4) may occur unintentionally. In this way, for instance, must be explained the appearance of fine longitudinal lines between the coarser real lines of Hipparchia Janeira which high power objectives exhibit under certain positions of the mirror.

XVII. The facts here recounted appear sufficient, when taken in connection with incontestible laws of the theory of undulation, to warrant a series of most important conclusions which affect the doctrine of microscopic vision, as well as the composition and manipulation of the microscope.

Firstly as respects the vision of objects under the microscope. Any part of a microscopic preparation which, either from its being isolated *(e.g.*, granules, single threads, or fibres), or from its relatively large dimensions (namely, to wave length of light), produces no perceptible diffractive effect, is delineated in the field of the microscope as an image formed according to the usual dioptric laws of rays concentrating in a focal plane. Such an image is entirely *negative*, being dependent on an unequal transmission of light which partial *absorption* of the rays *(e.g.*, colored rays), or divergence of the rays (from refraction), or diffraction of the rays (produced by particles of internal structure), severally occasion. *The absorption image thus produced is an unquestionable similitude of the object itself, and if correctly inter-*

preted according to stereometric rules, admits of perfectly safe inferences respecting its morphologic constitution. On the other hand, *all minute structures whose elements lie so close together as to occasion noticeable diffraction phenomena will not be geometrically imaged*, that is to say, the image will not be formed, point for point, as usually described by the re-union in a focal point (or plane) of pencils of light which, starting from the object, undergo various changes of direction in their entrance and passage through the objective; for even when the dioptric conditions requisite for such a process are fulfilled, the image so formed shews none of the finer structural detail, unless at least two of the diffraction-pencils which are caused by the splitting up of rectilinear rays are re-united.

Now to any one who clearly realises in his own mind what are the assumptions upon which a similitude between an object and its optical image is commonly accepted, the foregoing facts must suffice to lead to the conclusion, that under the circumstances above indicated such acceptance is a purely arbitrary supposition. As a positive instance of the contrary stands the conclusion to which experiments 4 and 5 lead by rigorous deduction, namely, that *different structures always yield the same microscopic images as soon as the difference of diffraction-effect connected with them is artificially removed from the action of the microscope; and that similar structures as constantly yield different images when the diffractive effect taking place in the microscope is artificially rendered dissimilar. In other words, the images of structure arising from the operation of the diffractive process stand in no constant relation with the real constitution of the objects causing them, but rather with the diffraction phenomena themselves, which are the true causes of their formation.* As this is not the place to enter into a physical exposition of such phenomena, it may suffice to say in brief, that the conclusions here deduced from facts won by direct observation, are fully substantiated by the theory of undulation of light, which shews not only why microscopic structural detail is not imaged according to dioptric law, but also how a different process of image formation is actually brought about. It can be shewn that the images of the illuminating surface, which appear in the upper focal plane of the objective, (the direct image and the diffraction images) must each represent, at the point of correspondence, equal oscillation phases when each single color is examined separately.

These aperture images, therefore, stand to each other in the same relation as the two mirror images of a flame in Fresnel's experiments on the interference of light. The meeting of the rays proceeding from them must occasion, in consequence of the occurring interference, a periodic alteration of light and dark, whose relative form and dimensions depend on the number, disposition, and mutual distance from each other of the interfering illuminated surfaces. *The delineation of structure seen in the field of the microscope is in all its characters,—those which are conformable with the real constitution of the object as well as those which are not so—nothing more than the result of this process of interference occurring where all the image-forming rays encounter each other.* The relation existing between the linear distances from the axis of the microscope of constituent elements of the aperture image, and the various inclination of rays entering the objective, (explained and formularised in section II., 4) taken together with the dioptric analysis of the microscope, as set forth in 6, afford all the data necessary for complete demonstration of the above positions. From them may be deduced that in an achromatic objective the interference images, for all colors, coincide, and yield as a total effect achromatism, thus differing from all other known interference phenomena. Further, that the proportionate dimensions of the images so produced always depend in such wise upon those of the actual structure as the linear magnifying power of the microscope would bring, according to the dioptric law of formation of images, whatever be the arrangement of the optical parts or the mode of illumination. And all the facts stated in the 16th paragraph are not only fully accounted for, but beyond this it is possible to calculate beforehand, in all its details, the delineation of structure imaged by any particular object under any definite illumination, if only the actual effective diffraction phenomena be given, namely, the number, disposition, and relative brightness of all the diffraction spectra.

XVIII. The final result of these researches may be thus stated.—

Every thing visible in the microscope 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 (*e.g.*, striæ, or mapped out fields, &c.) they cannot be interpreted as morphological, but only as physical characters; not as *images* 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 which the images of minute details depend.*

The smaller the linear dimensions of structural elements are, the fewer in number will be the diffraction pencils which come into operation even with the largest possible angle of aperture: the less effectively can the gradation of intensity in the series of these diffraction rays bring into view such structural differences as are still possible within the same relation of dimensions; and the more indefinite will be the conclusion to be drawn from the image, or even from any visible diffraction phenomena, respecting the true structure of the object.

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 angm. possesses two or three sets of striæ; whether striation exist at all; whether the visible delineation is caused by isolated prominences, or depressions, &c., no microscope however perfect, no amplification however magnified can inform us. All that can be maintained is the mere presence of conditions optically necessary for the diffraction effect which accompanies the image-forming process. So far, however, as this effect is visible in any microscope (six symmetrically disposed spectra inclined at about 65° to the direction of the undiffracted rays, ordinary direct illumination being employed) it may proceed from any structure which contains in its substance, or on its surface, optically homogeneous elements arranged with some approach to a system of equilateral triangles of $0{\cdot}48\mu$ dimensions ($=$circa $\frac{1}{52000}$ inch.) Whatever such elements may be— organised particles or mere differences of molecular aggregation (centres of condensed matter) they will always present a delineation of the familiar form. All ground for assuming these elements to be depressions or prominences, fails, after proof that neither the visibility of the markings, nor their greater distinctions under oblique illumination, has anything to do with shadow effects.* The distribution of light and shade on the surface of the valve in the form of a system of hexagonal fields, is the mathematically necessary result of the interference of the seven isolated pencils of light which is caused by diffraction, whatever may be the physical condition of the object causing this diffraction: the position of the hexagonal fields, with two sides parallel to the middle ribs, has its sufficient reason in the visible disposition of the diffracted spectra towards the axis of this valve, and can be

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* The changes which the image of Pleurosigma angm. undergo when the microscope is raised from or lowered upon the object, prove nothing in respect to the existence of elevations on its surface, for the same changes occur in the same way when diamond ruled lines on glass are examined. And besides, when a sharply defined light is viewed through a Pleurosigma valve, according to the method already described, no divergence from the refraction of the rays passing through it can be recognised—the valve behaves in this respect just as if it were a glass plate with parallel surfaces.

deduced by calculation without any necessity for knowing the actual structure of the object.

That the same state of things obtains in numerous instances of organic forms, the study of which belongs to the province of Histology, we may learn from the instance of striated muscular fibre. In good preparations the diffraction phenomena are readily observed and may be studied experimentally by the methods already described. The manifold changes in the characters of the images which then present themselves account, to a certain extent, for the notorious discordance between the representations of different observers, and also attest the impossibility of interpreting in any satisfactory manner the material composition of this tissue, in the sense in which it has been hitherto attempted. What has been here urged respecting the principles upon which microscopic vision depends applies further, not only to the morphological relations of objects, but, in quite as great a degree, to other properties, concerning which microscopic observation is expected to afford correct conclusions. That many distinctions of transparency and of colouring perceived in the microscopic image do not necessarily indicate any special character of the object, but often arise from partial or entire exclusion of diffraction pencils, is a fact sufficiently illustrated by the known appearances of diatom valves. It seems also of importance to note that the signs of polarisation in the images of objects containing minute detail must be in many respects differently interpreted from the polarisation effect in purely geometrical or "absorption" images. To make inferences, in an ordinary sense, concerning the double refraction of substances is, to say the least, full of hazard; for there remains always the possibility that the same textural peculiarities which call forth diffraction, may, under circumstances, originate at the same moment polarisation effects, which, so far as these are attributable to the function of diffraction, do not depend, as in crystals, starch, granules, &c., &c., upon peculiar transmission of light rays. That something of the kind does actually occur appears probable from what I have seen when observing Pleurosigma angm. and other diatoms, which, seen under polarised light, shew modifications of diffraction which it would be difficult to explain otherwise. However this may be, it is no longer admissible, in an object, for instance, such as muscular fibre, whose structural detail is not dioptrically imaged, to conclude according to ordinary criteria, from observation of changes of the diffraction image in polarised light, that the various elements possess alternating characters of simple and double refraction; for if any *homogeneous* doubly refracting substance were present with differentiation in its substance sufficient to produce the existing diffractive effect, then an appearance of striation would arise from interference of the polarised diffraction pencils, shewing exactly the same modifications as muscle fibre does under polarised light.

XIX. In connection with the foregoing conclusions, which have an important bearing on the scientific application of the microscope, it appears, further, that the limits of "resolving" power are determinate for every objective and for the microscope as a whole.

No particles can be resolved (nor the characters of any really existing structure recognised) when they are situated so closely together that not even the first of a series of diffraction pencils produced by them can enter the objective simultaneously with the undiffracted rays. From this it follows that for every degree of angular aperture there must be a fixed *minimum* of distance of separable elements, which cannot be stated in exact figures, for the reason that this minimum differs for every colour on account of their unequal wave lengths, and also because the relative significance of the several colours varies greatly. Taking any given colour as a basis, the respective minimum value is found (purely central illumination being employed) by dividing the wave length by the sine of half the angle of aperture, and half that product when, other circumstances being equal, the illumination is as oblique as the objective will admit, whatever be its aperture. As, therefore, even with immersion objectives the angular aperture cannot, by any possible means, be increased beyond the degree which would correspond, in effect, to 180° in air, it follows that whatever improvement may be effected in regard to serviceable magnifying power, the limit of resolving power cannot be stretched sensibly beyond the figure denoting the wave length of violet rays when direct illumination is used, nor beyond half that amount when extreme oblique illumination is used. The last limit is, in point of fact, already reached by the finest lines of the Nobert plate and the finest known markings on Diatom valves, as far as *seeing* is concerned. Only in the photographic copy of microscope images can resolution of detail be carried any further. Here, in consequence of the considerably shorter wave length of chemically acting rays, the conditions for photographic reception of the microscopic image are much easier for every objective, inasmuch, namely, as they present a picture which would be in the proportion of 3 : 2 larger in its details than is seen by the eye. For this reason alone, apart from all others, the performance of an objective in photography does does not express the real measure of its performance in the ordinary use of the microscope.

SECTION IV.—*The optical power of the microscope.*

XX. The foregoing researches afford a sound basis for an accurate determination of the nature of those functions which constitute the real optical power of the microscope, and, at the same time, for arriving at some rational definition of the performance which may be expected from our present optical combinations.

The distinction so long recognised between "defining" and "resolving" powers receives, through the facts and proofs here brought forward, a far wider significance than could fairly be attributed to them upon any previously known grounds. From these facts it appears that the microscope image—excluding two cases of a similar and exceptional kind—consists, as a general rule, of *two* superimposed images, each being equally distinct in origin and character, and also capable of being separated and examined apart from each other. Of these, one is a *negative* image, in which the several constituent parts of an object re-present themselves geometrically, by virtue of the unequal emergence of light which is caused by their mass affecting unequally the transmission of the incident rays. This image may, for shortness sake, be called the "*absorption image*," because partial absorption is the principal cause of the different amount of emergent light. It is the bearer of the "defining" power, whose amount is determined by the greater or less exactitude with which direct incident light is brought into perfect homofocal reunion, the condition under which images of this kind are produced. Consequently, it is always the *direct* light—just as it comes from the illuminating source—which "defines," no matter in what direction it arrives at the objective, *i.e.*, whether the central or peripheral zones of the objective receive it. But, independently of the "*absorption image*," all such parts of the object as contain interior structure will be imaged a second time, and this time as a *positive* image, because these parts will appear as if self-luminous, in consequence of the diffraction phenomena which they cause. This second image which may be called the "diffraction image," consists, strictly speaking, of as many partial images as there are separate diffraction pencils entering the objective since each of these produces a positive image, as shewn in the experiments before mentioned. But as these partial images, taken singly, are void of content, and visible details appear first only when two or more of them blend together, the total effect (*i.e.*, their fusion into one image) is that which must be practically regarded as the independent factor. Now this "diffraction image" is manifestly the bearer of "resolving" power, that is, the discriminating or separating faculty of the microscope. Its development depends, therefore, in the first and chief place upon angular aperture, in so far as this alone determines, according to rules above given, the *limits of its* *possible operation.* But its *actual* amount will, at the same time, depend upon the exactitude with which the partial images corresponding to the respective diffraction pencils blend together: for it is through this last act, that the detail which indicates the existence of positive structural elements in the object is rendered visible. Now, inasmuch as these isolated pencils, whose confocal reunion is the necessary condition of the formation of diffraction images, occupy different parts of the aperture, and vary constantly in position according to the character of the object and the mode of illumination: it is obvious that a perfect fusion, in *every* case, of the several diffraction images, and then an exact super position of the resultant "diffraction image" upon the "absorption image," is only possible *when the objective is uniformly free from spherical aberration over the whole area of its aperture.*

XXI. According to the authoritative representations hitherto given of the process by which an image is formed in the microscope, one might suppose that residual aberrations in the objective only impair the sharpness of definition, and that such aberrations either did not exist, or might be considered, as practically, of no importance so long as there was no visible failure of definition. But the facts shewn above, taken in connection with what has been said (paragraph vii.) of the typical form of spherical aberration in objectives of large angular aperture, place their significance in a very different light. The several elements of the microscope image, namely, the "*absorption image,*" and the several constituent "*diffraction images*" are produced by isolated pencils of relatively small angle of divergence scarcely ever beyond 30° to 40°. And even with a considerable residual spherical aberration, the points of such isolated pencils, each considered by itself, are sharp enough to leave scarcely any noticeable dispersion circle. As however, with a large aperture these separate pencils operate through very different parts of the aperture at the same moment, their focal points cannot re-unite if the residual spherical aberration is considerable, but must appear *beside* or *behind* each other. Hence the component parts of the total image do not blend together correctly, but will be thrust out laterally or backwards. Marks of structure which belong in the object to one and the same place and level (*e.g.*, various systems of lines) appear separated from each other, and also from the points in the object to which they belong. In consequence of the onesidedness with which, in modern times, the improvement of the microscope has been directed towards the increase of angular aperture, the conditions under which abnormal appearances, and especially deceptive alterations of level are produced, occur abundantly in the new high power objectives, as repeated experience has shewn me, and I assuredly do not err in expressing my conviction that the consequences of this state of things affect to an unexpected extent the numerous questions in dispute amongst microscopists, concerning the interpretation of minute structures.

Since every one must admit that the first and most imperative claim which can be made, in the interest of scientific microscopy, upon the performing power of the instrument is *this*—that parts which belong together in the object shall also appear as belonging together in the microscopic image, it follows that uniform correction of spherical aberration throughout the whole area of aperture must be the absolute criterion and rule of guidance in the construction of a microscope. Now, it has been shewn (paragraph vii.) that with a dry objective an adequate compensation of spherical aberrations is, as a matter of fact, impossible when the angular aperture exceeds 110°. Hence it must be concluded that a dry objective will be less suited for ordinary scientific use in proportion as it renders visible such finer systems of lines as exceed the limits of resolving power answering to that angle (namely, 0.35μ for oblique light). The greatest possible increase of resolving power can be obtained in a rational way only by means of immersion objectives, as these alone admit of the largest possible (*i.e.* technically practicable angular) aperture, without contravening the very first requirement of corrected spherical aberration. *

XXII. In connection with the foregoing statements, a few hints respecting the most suitable modes of testing microscopes may be here given. According to past experience, it would be considered justifiable to estimate the worth of an objective according to the minuteness of ultimate detail which it might render visible, and, acting upon this view, to consider the resolution of difficult test objects as the proof of highest performance. For though it could not be denied that the particular kind of detail in these test objects, and the particular mode of illumination applied to them are not such as occur in ordinary work, it might, at least, seem beyond doubt that the same peculiarity of construction which gave so good a result in these exceptional cases must be operative in ordinary work. This must, however, now be objected to, for the reasons above given. A mode of testing which turns upon the determination of the utmost limit of "resolving power," whether tried upon a "Nobert" plate, a diatom, or an insect scale, brings into play a quite exceptional direction of rays of light into the microscope, such as is, indeed, required for this purpose by the physical condition of the problem,

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* The dry objectives made on Abbe's calculations, founded upon the principles before explained, have only 105 to 110 deg. of angular aperture for the highest powers, and cannot pretend, therefore, to compete, in resolving diatoms, &c., with objectives of much higher angle. The immersion lens is constructed with a free aperture of about 100° in water, *i.e.*, somewhat more than would correspond to 180° in air, because this is attainable without serious disadvantage. Professor Abbe is, however, convinced that even the immersion lens would not lose any of its value for ordinary scientific purposes, whilst it would be materially improved in many respects if its construction were based upon calculations for a smaller aperture, "but," he adds, "in view of this universally accepted standard of valuation,' the practical optician can scarcely be expected to trouble himself about qualities of performance which would be very certainly ranked amongst those of a secondary order!"

but which need not be repeated for any other kind of operation; for detail only approaches the limit of resolving power when it is so minute, and causes so strong a dispersion of light by diffraction, that even under the most favourable circumstances only the first deflected pencil can enter the objective simultaneously with the direct rays. And when it is visible in the image, this is only accomplished by the operation of the outermost peripheral zone of the aperture. The most oblique incident pencil which the mirror can deliver streaks the edge of the aperture on one side, and the single diffracted pencil which gains access streaks it on the other side, as may be proved by direct observation of the tracks of both pencils in the upper focal plane of the objective. But theory and practice teach us that every objective which is not a total failure—however imperfect in respect to correction of spherical aberration—if its lenses be but moderately well centred, can always be made to work with *one* of its zones, *e.g.*, the outermost, and this permanently, if during its construction it has been tried on a similar test; and if it be furnished with a correction collar (adjusted during use, to throw the action upon the periphery of the lens), an arrangement which is, in fact, much oftener employed for this than for its ostensible purpose (correction, namely, for thickness of glass cover).

The proof that an objective can resolve very minute striæ on a diatom or Nobert's test plate, attests, strictly speaking, nothing more than that its angular aperture answers to the calculable angle of diffraction of the interlinear distance of the striæ on the test, and that it is not so badly constructed that a sufficient correction of its outer zone is impossible. A trial of this sort offers no means of ascertaining what conditions for the correct fusion of aperture images such an objective would present in the much more unfavourable case of the ordinary observing position, where one or more zones in various parts of the aperture are almost always taken up at one and the same time with rays that are in effective operation. Nor can the result be considered as sufficiently characteristic even of the "resolving power" in its more general attributes. It only gives the *limit* of resolution, and therewith establishes a fact which may have a certain value in itself, on account of the singularity of the case, but which has no direct connection with the general performance of the lens.

Nor can the test of "resolving power" by direct light be estimated at a much higher value. In the neighbourhood of the limit of resolution corresponding to this form of illumination, all direct light passes through the central zone, and all diffracted light through the peripheral zone of the aperture. Independent of the circumstance that residual aberration can be thrust into some non-operative middle region by help of a correction collar, the fact of resolution depends, even in this case, essentially upon the action of the peripheral zone, because there always lie, at least two, if not more, oppositely situate diffractive pencils in the periphery, which, with even indifferent co-operation of the direct rays, render details visible.

From the point of view presented by the theory here propounded, another method offers itself, which, while employing the usual tests, brings directly into light the particular points which mainly influence the quality of performance during ordinary use of the microscope. If it be desired to test, in a most critical way, the conditions of exact co-operation of pencils of light which pass through every part of the aperture, there are truly no better means than those afforded by natural objects of the Diatom class and insect scales, provided that the mere fact of accomplished "resolution" is not made the chief consideration, but that the exact constitution of the total image produced by the objective is studied.

If, for the test, an object be chosen whose fineness of detail is such that the objective to be tested just enables it to be seen with direct illumination, and therefore without any difficulty with oblique light, it can be made, without any further preparation, to bring to view the *sensitive* track of light through the microscope, the production of which is effected by the mode of testing mentioned in paragraph x., where an artificial test object is illuminated with two isolated pencils of light. The divergence of the first diffraction pencil obtains in this case such a relation to the angular aperture of the objective that—as theory and direct observation of the tracks of light shew—by setting the mirror in two special directions, *parts* of *all* the zones of the aperture, each represented by separate lines of light, will be set at work under circumstances which strongly conduce to bring out any existing failure of correction. One position of the mirror would be, when placed with its inner edge just outside the axis of the instrument, the whole of the mirror being then on one side of the axis and its surface turned at right angles to the striæ in the object, so that the track of the *direct* incident light would appear in the aperture-image above the objective, close to its centre, whilst the track of diffracted ray would appear in the periphery on the opposite side. The second position would be that of greatest oblique illumination which the objective would bear without marked loss of light. The tracks of the two pencils would, as soon as this change of illumination was effected, simply exchange places. In both cases there would be—supposing the object to contain only *one* set of striæ—two isolated pencils set in action which would engage a portion of the central and a portion of the peripheral zone of the aperture on opposite sides of the axis at the same time. But if the object contained several uniform sets of striæ, although additional diffraction rays would pass through the objective, no essential change of the relations before noted would take place.

The intention of this procedure is not, of course, to discover each particular fault in the image-forming quality of an objective, as can, indeed, be done by the method described in paragraph (x), but to test, in a general way, the actual performance of a lens in such a manner as would represent the normal state in ordinary use of the microscope. The factor of chief practical importance reveals itself at once when attention is given to the degree of correctness with which the fusion of the several partial images which belong to one and the same part of the object takes place. We have the outline image of the object as formed by the direct light, and, at the same time, a detail image of content, which is produced by the interference of diffractive rays. When the objective is corrected properly, each image stands out sharply defined by itself, whilst both fall accurately together without difference of level in any lateral displacement —that is to say, both images are clearly seen, with *one* setting of focus, when in the object itself outline and structure are on the same level. If a system of lenses works satisfactorily under a trial of this kind, carried out with a few turns of the fine movement screw, or, at least, if it performs well in the middle of the field, we may be sure that it will always give correct images of any object, and with any kind of illumination. On the contrary when—the objective being focussed for outline image—details appear to hover above or beneath it, or float away, sidewards, from it, a construction of objective is indicated, which offers no certainty that markings which belong together in any given preparation will be recognised as belonging together in the microscope image, however highly the "resolving power" may exhibit itself with the usual mode of testing it.

Without limiting the mode of illumination to the two positions already described, the judgment may be assisted in various points when other positions of the mirror are tried and their effect proved, attention being always directed to the characteristic signs of fusion of the partial images. But in every trial it is scarcely necessary to observe that the effective course of the rays must be controlled by direct observation of the aperture images.

In all large-angled objectives, deviations of the kind alluded to will be observed in the outer circle of the field of vision, unless the visual angle of the eyepiece be unusually small. They arise, not from aberration, but chiefly from differences of amplification, which are unavoidable even in the best objectives. The extent to which they occur is the measure of relative imperfection of the image formed outside the axis. What further belongs to our judgment of the good qualities of a system of lenses may be gathered from examination of the coloured fringes which appear on the outlines of the object, in the centre and outside circle of the field of vision. But it must be borne in mind that aberrations of this kind, as they mostly occur in outline images, have a practical significance only when, during ordinary microscope practice and with direct light, they appear prominently with a central position of the mirror.

In the test objects used for the above trials, two precautions are necessary. Firstly, they must be *thin* and *even*, in order that outline and structural detail may be seen lying in the same level; secondly, the diffraction pencils must possess a great intensity of light, in order that the effect produced by them may be fairly appreciated in comparison with the effect of the image produced by direct light. For this last reason objects prepared *dry*, with vigorous and strong markings, are most suited for tests, as they always give—as may be seen in the aperture image—the brightest diffractive phenomena, because the interference of intensely bright rays is required to bring out strong contrasts of clear and dark parts in the microscope picture.

For low and middle power objective an abundance of suitable objects may be selected from insect scales and the coarser diatoms. For the higher powers, on the contrary, the selection is limited, because of the necessity of *thin* and *even* preparations. The "Nobert-plate" is unsuited for this kind of trial, since it gives *no* "absorption image," but a pure "diffraction image," and therefore the most important element for judging of the action of a lens, fails in this case. *Pleurosigma angulatum* corresponds, perhaps, best, in regard to fineness of detail, to the angular aperture of immersion lenses, and may, in fact, be employed for the highest powers when fragments of delicate specimens with sharply fractured edges are selected, and attention paid to the quality of the image close to such a fractured edge. But neither the natural edges nor the middle rib offer any certainty of uniform level. To test the high power dry lenses, fragments of coarser specimens of the same object can be used, though the markings are almost too fine for an angular aperture of 100°. Fragments of fine scales of Hipparchia Janeira, the cross striæ of which are equal to angular aperture of from 80° to 90°, are also serviceable. According to my experience, a very safe estimate of the quality of an objective may be formed after a little practice with the method here recommended. At all events, the amount of optical capacity, in regard to those functions which are independent of mere angular aperture, may be more correctly estimated than is possible with trials of "defining and "resolving" power worked out separately.

What, however, this method does *not* give—namely, the absolute limit of physical discriminating power, may be as readily obtained by direct calculations from measurements of angular aperture as by direct observation of test objects.

XXIV. In conclusion, certain general deductions respecting the construction of the microscope which follow necessarily from the doctrines and facts above given may be stated.

The optical capacity of the microscope depends, according to our theory, upon two factors, which have their origin in two different elements of construction. The first is the geometrical accuracy of the course of rays; it determines, through the magnitude of dispersion circles on the image, the size of the smallest details which can, geometrically taken, find expression therein. The second factor is indicated in the capacity of the objective to fulfil certain physical conditions with which the repetition of these details is at all events connected, namely, the integration of the pencils of light split up by diffraction, without which the image remains bare of contents. As on geometrical principles detail is not imaged when its magnitude is less than that which expresses the diameter of the dispersion circles (reduced to the linear dimensions of the object), so on physical grounds detail is not imaged when the angular dispersion of the diffraction pencil is so large as to render their re-union impossible (even of two pencils only). Now the condition for both functions are alike, as has been already shewn, rooted in the objective alone, but they are rooted in entirely different elements of its construction. The *dioptric limit* of resolution caused by inevitable defects of focal union of the rays of light, finds its measure in the *serviceable* amount of *magnifying power* of the objective, and is inversely proportional to its focal length. The *physical limit* of resolution, on the other hand, depends *wholly* on *angular aperture*, and is proportional to the sine of half the angular aperture. Nevertheless, both functions conduce toward one and the same end, namely, the rendering visible particles of matter which fill infinitely small space, and both are equally necessary for this end. Hence it follows that a rational construction of the microscope must aim at a due balance of powers in order that the limits of each may approximate harmoniously; for it is obviously just as useless to carry out the physical conditions of "resolving" power, to an amount greatly in excess of that which can be utilised by any attainable (and still serviceable) amplification, as it would be, on the other hand, to increase the magnifying power beyond that which the amount of "resolution" demands. In the first case, where the angular aperture is in excess of the serviceable amplifying power pertaining to the focal length of the objective, there is a *latent* power of resolution which is lost to every eye; in the second case, when the magnifying power of the objective exceeds the dioptric limits of resolution greatly beyond that which the detail accessible to the aperture of the objective requires, an *empty* amplification (that is to say, one in which proportionate detail is absent) is the consequence.

XXV. The considerations here adduced lead to certain rules respecting the right proportion between focal distance and angular aperture, which are opposed in many points to the hitherto prevalent practice. The remarks which follow are supplementary to what has been stated in paragraph ix., and may be of general interest as tending to shew the extent and the limit of microscopic observation.

Since theory demands a limitation of angular aperture of 110 degrees for all *dry* combinations, the calculation of minutest detail accessible to such objective is readily made; and it may be shown that if "resolving" power be not unfairly exalted at the cost of the general excellence of the lens, there can be no question of detail which a practised eye would not recognise with a good amplification of from 4 to 500. Now according to the present standard of technical constructive means, such an amplification may be gained with an objective of 3 mm ($\frac{1}{8}$th English inch), even if the attribute *good* be interpreted a little more strictly than is often done. With immersion lenses, the physical limit of "resolution," even where the angular aperture is the highest attainable, does not extend so far that an amplification of from 7 to 800 will not be fully equal to it; and this amplification would be gained with ease with a well constructed objective of $\frac{1}{12}$ inch focal length. It may be admitted that an amplification exceeding the minimum here given, as theoretically necessary, might greatly facilitate observation and render it more certain *if* the additional amplification be as correct as can be possibly made, although it would not occasion any new facts to be seen. Yet one can scarcely estimate the significance of this empty amplification far beyond the limits stated, and I therefore come to the conclusion that the scientific value of an objective whose focal length (if a dry system) is much shorter than $\frac{1}{12}$ inch, or if an immeraion system, than $\frac{1}{25}$ inch, is altogether problematical.

The actual powers of the microscope (in the strict sense of correct and useful power) are, in my opinion, exhausted at these limits, so long, that is, as no circumstances of moment are brought forward which change the bearing of present theory, There exists no microscope in which there has been seen, or will be seen, any structure which really exists in the object, and is inherent in its nature, that a normal eye cannot recognise with a sharply defining immersion lens magnifying 800 times. Reports of extraordinary performances (especially from England) of unusually high power ($\frac{1}{80}$ inch?) are not of such a character as to induce me to change my opinion and lead me into similar error, for the superiority of such lenses is said to have been proved upon objects to which the results of my observations unreservedly apply, and which are said to appear under such amplification as every one who can understand and give an account to himself of the optical conditions of such performances must know to be wholly illusory.

Postscript by the Translator.—In the theory of the microscope here presented, a point of great interest is raised, in considering the influence which the minute structure of an object exerts upon rays of light passing through it. From this point of view, the chief significance of the function known as "resolving power" of an objective is rightly transferred to the structural condition of the *object*, as being the prime cause of certain optical phenomena connected therewith, whilst the part played by the *objective* is of a more passive kind. The microscope picture, however true and consistent with optical law, may, indeed, in so far as it suggests any false inference respecting the intimate structure of an object, be spoken of as an optical illusion, although both the suggestion and the false inference arise in the observer's mind and cannot be charged to the objective, provided this latter be correctly constructed for its own proper function. There is, unfortunately, no lack of opportunity for misinterpreting optical phenomena in attempting to supply, or imagine, a material cause for them!

It is, however, clear that the first beginnings of that wonderful series of refractions, dispersions, and recompositions of light which finally result in the production of an enlarged and colourless image, must be sought for in the object itself, whether the microscope picture be simply a geometrical delineation or a compound of negative and positive images superimposed on each other. On all hands, it is agreed that suitable illumination of each single object is a necessary preliminary to the most effective resolution of its details. But until the present time this "resolving power" has been credited to the objective as its special function and attribute, though its *modus operandi* has not hitherto been satisfactorily explained. The fact that so striking a physical change in the condition of the illuminating rays takes place, under certain conditions, in the *object itself*, and that this change is entirely due to the structural constitution of the object, greatly enhances the importance of suitable methods of illumination, and shews us the need of a most careful study of the physical conditions under which an object is presented to the objective. Good illumination is thus not only "half the battle," but being also the *first* half, determines the subsequent action of the objective, for the rays which fall upon the front lens of the combination (derived in the first instance from the source of illumination employed) take, so to speak, a fresh start from the separate constituent elements of the object. A portion of them undergoes more or less complete absorption, or passing through relatively transparent parts, suffers but slight change; whilst for another portion, diffraction, under given circumstances, breaks the fine pencils which fall upon minute elements of the object into separate groups of rays, which take a different course from the undiffracted rays, so that additional images of these details are formed which appear as if self luminous, whilst waves of interference are initiated which occasion shadow. And all this happens *before* the action of the objective commences; waves of ordinary and diffracted light entering together, and thus potentially determining beforehand the constitution of the microscope picture about to be formed.

For the admission of rays of *all* degrees of angular divergence from the axis of the microscope, (*i.e.*, the whole sweep of 90° in either side of the zenith down to the horizon) the front lens of an objective must be a hemisphere, with its plane surface turned towards the object, and such a lens is as simple as it is efficient, "*ad hoc.*" But in all further dealing with the light thus let in, mathematical science and technical skill are needed for the correction of errors of focussing function, and of chromatic dispersion inseparable from the material condition of the problem to be solved, namely, the final re-union, at the eye-point above the ocular, of all these rays in a focal plane, which exhibits the outspread picture of the object from which they came. Or, remembering that light is motion, we might say that focal plane in which are assembled, in equal phase of motion, the whole sum of undulations which started from the object beneath the microscope.

All that takes place through the combined function of objective and ocular, *i.e.*, the microscope as a whole, is the presentment to the eye, in amplified delineation, of an image of that which is actually or partially existing in the prepared object. The particular calculations for, and corrections of, the lenses of the objective-system concern only those causes of error which are inherent in its own construction, and do not apply in correction of any faulty illumination of the object, *i.e.*, do not counteract any excess or deficiency or misdirection of the illuminating rays. Of course, an objective which is most perfectly corrected, and takes in the largest possible number of illuminated parts of the object without loss of defining power, "performs" better than one less skilfully constructed, but it adds nothing to the actual detail in the object, as also, if a really good lens, it takes nothing away. Its best performance depends on suitable illumination; on the other hand, it may fail to shew what actually exists in an object, not because it is an ill-constructed objective, but simply because of inefficient or improper illumination, or because the test is disproportionately severe.

A theory of the microscope is, therefore, not complete until the principles are clearly laid down by which the intensity of illumination of the magnified image may be regulated and controlled, and by which, moreover, the mode of action of illuminating apparatus of all kinds may be analysed and estimated at their true worth. Professor Abbe has briefly enunciated these principles in the essay from which the foregoing pages are translated. But for reasons already given this statement has been omitted in the present communication. It had been my intention to review the whole subject of illumination of objects for the microscope in another paper and at a later period. I here only direct attention to a translation, published in the *Monthly Microscopical Journal* (April, a.c.), of an article written by Professor Abbe which appeared in Schultz's *Archive* (at the same time with the longer essay here translated), and which gives an account of an illuminating apparatus invented by the author. In the English journal, however, an introductory discussion of optical principles, (written by the author and referring to what had been written in his former communication), is omitted. There is still ample room for a general review and discussion of the whole question. The practical importance of suitable illumination for all classes of objects has been fully shewn in this essay, and apart from all theoretical considerations, it is no slight evil that the time notoriously wasted in trying useless combinations and methods of illumination should result, as not unfrequently happens, in the discredit of the best qualities of an objective, or what is indeed a still more common case, an objective is credited with qualities which it does not possess, but which if it did would be of very questionable value. Until, moreover, the the optical principles by which the construction of illuminating apparatus should be regulated are definitely formularised and generally acted upon, condensors and illuminating apparatus—some more or less serviceable, others useless or mischievous—will continue to be made and pressed upon public attention, to the further confusion of a matter that has already suffered too many false issues.

Geology of the Bristol Coal-field.

PART 2.—SILURIAN AND DEVONIAN.

BY W. W. STODDART, F.C.S., F.G.S.

HAVING described the igneous rocks of the Bristol district, we now commence our study of the sedimentary deposits that afterwards were formed by aqueous and atmospheric agencies, and which, having gradually accumulated, formed the bottom of the ocean.

It was through these ancient sea beds that the molten masses were protruded from the interior of the earth with powerful and irresistible force. The British Isles owe their present existence to the submarine eruption of fluid lava at an immensely remote period. On looking at a geological map their ancient monuments may beseen studding the western parts of England and Scotland. As time elapsed, the wind and tide wore away these apparently hard rocks, and deposited the muddy and sandy *débris* which, after consolidation, formed what we now see as the bottom rocks of Wales, Scotland and Ireland. When these had reached the depth of many thousand feet, and the bed of the ocean had become suitable for the lowest sea weeds, and animals of the Molluscan, Annelidan and Crustacean kind, the muddy strata of the Lower Silurian period appeared. As, however, we do not find any of these are exposed to view within the limits of our district, we must pass them and examine the Upper Silurian deposits, which must be taken as the earliest beds, and base of our exploration in the Bristol Coalfield.

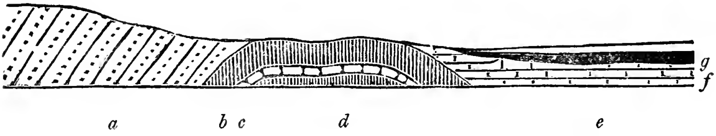
We are fortunately able to examine these Silurian beds in the neighbourhood of Tortworth and Falfield, where they are brought to the surface within our reach, and afterwards well exposed for study by denudation. These strata are a continuation of the rocks of Mayhill, Huntley, and Woolhope. At Flaxley the Silurian beds dip beneath the Devonian rocks, and re-appear at the eastern bank of the Severn at Purton, where they may be seen as an anticlinal.

The Silurian deposits within the boundaries of our map are divided into three groups,—the Upper Llandovery or Mayhill Sandstone, the Wenlock Limestone and Shale, and the Ludlow Shales.

I. *The Upper Llandovery Sandstone.*

At Purton these beds are too deeply seated for observation; there the upper groups only appear, and are exposed at the lowest tides, as seen in the following section.

FIG. 4.—*Section near Purton.*



a Devonian.—*b* Ludlow.—*c* Wenlock Limestone.—*d* Wenlock Shales.—*e* Trias.—*f* Rhætic.—*g* Lower Lias.

The most northerly point in which we come into contact with the Upper Llandovery beds is at Malford Common and Swanley Green. It then continues through the Tortworth district, where it may be studied for a distance of three miles, from Conderford Bridge to Whitfield. The Upper Llandovery may be considered as the passage beds between the Lower and Upper Silurian. They consist of micaceous sandstones and shales, having altogether a thickness of 1000 feet. Some are nearly all sound, while others are very argillaceous and fissile. The most fossiliferous beds are on the Sandstone, where they may be easily found by the purple colour and burnt appearance of the stone. These and the thin shales may be found near Damory Bridge. Here the fossils are extremely abundant and tolerably well preserved. An excellent spot is at the road side, a few yards west of Damory quarry. So rich is this spot that the student may spend an hour or two over a good block of the stone, and fill his vasculum with a good suite of typical fossils. From this spot to the trap quarry the mineralogist may find a most interesting series of specimens shewing the gradual change of loose sand into solid and compact quartz.

The following is a list of the fossils that most frequently may be met with in the Llandovery beds of the Tortworth district:—

Petraia bina (Lond.)
    subduplicata (Mc Coy.)
    elongata (Phill.)
Favosites Gothlandica (McCoy.)
    Forbesi (M. Edw.)
    Hisingeri (M. Edw.)
Tentaculites Anglicus (Salt.)
Cornulites serpularius (Schl.)
Phacops Stokesii (M. Edw.)
    Weaveri (Salt.)
Stricklandinia lens (J. de C. Sow.)

Pentamerus oblongus (J. de C. Sow.)

Rhynchonella decemplicata (Sow.)
  nucula (Sow.)
  Llandoveriana (Dav.)
  Weaveri (Salt.)

Atrypa hemispherica (J. de C. Sow.)
  reticularis (L.) var. orbicularis.

Spirifera elevata (Dalm)
  exporrecta (Wahl.)
  crispa (Hisinger.)

Strophomena rhomboidalis (Walck)
  arenacea (Salt.)
  compressa (Sow.)

Orthis reversa var. Mullockiensis (Salt.)
  calligramma (Dalm.) (not flabellulum.)
  elegantula (Dalm.)

Pterotheca sp.

Pterinea retroflexa (Wahl.)

Modiola sp.

Euomphalus funatus (Sow.)
  sculptus (Sow.)

Cyclonema ventricosa (Hill.)

Raphistoma lenticularis (Sow.)

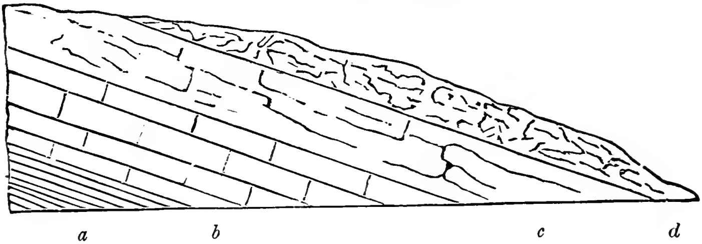
Holapella obsoleta (Sow.)
  gregaria (Sow.)

Bellerophon trilobatus (Sow.)

II. *Wenlock Shales and Limestone.*

These beds may be seen throughout the neighbourhood of Tortworth, Avening Green, Falfield, &c., The following section may be seen in the middle of a field near Falfield Mill.

FIG. 5.—*Falfield Section.*



a Coloured schist.—*b* Purple encrinital limestone.—*c* Irregular limestone with corals: Encrinites, Spirifer, Orthis, &c.—*d* Rubble beds.

1. At the top is a rubbly bed with fossils, but all in a very imperfect state.
2. Limestone having a purplish colour, apparently derived from animal matter, irregularly bedded and containing a great number of fossils, such as Wenlock corals and Encrinites, Spirifer radiatus, Orthis elegantula, &c.
3. Purplish limestone, with numerous remains of Encrinites.
4. Red and green schists, the base of which is not exposed.

In this section all the beds dip to 45° east. Not far from Tortworth Court is an anticlinal, a section of which is now and then exposed (fig. 6). At a fortunate visit, when a small opening was made, the following list of fossils was obtained:—

Crania implicata (Sow.)
        Siluriana (Dav.)

Spirifera sulcata (Dav.)
        plicatella. var. radiata (Dav.)

Meristella didyma (Dalm.)

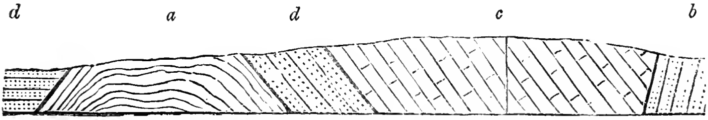
Rhynchonella borealis (Schlok.)
        navicula (Sow.)
        Wilsoni (Sow.)

Orthis elegantula
    basalis (Dalm.)

Strophomena Waltoni (Dav.)
    depressa
    englypha

Corals and Encrinites

Fig. 6.—*Tortworth Anticlinal.*



a Upper Silurian.—*b* Devonian.—*c* Carboniferous.—*d* Trias.

The Orthis basalis and Crania Siluriana are fossils as yet only found in the Falfield district. Another section may be examined near Avening. Here the Wenlock coral bed is actually lifted up by an outburst of lava, with the corals altered by the heat.

III. *The Ludlow Shales.*

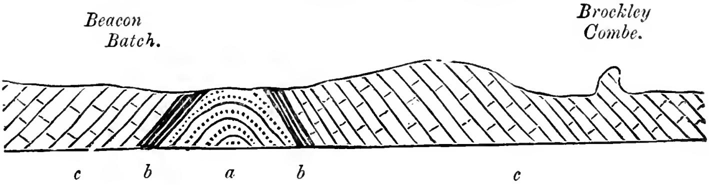
These, although so extensively extended over the country, are not well placed for the collection of fossils. For this reason no satisfactory list of fossils can be made.

THE DEVONIAN.

The Devonian, or Old Red Sandstone, in the neighbourhood of Bristol, comprises Sandstones, Shales, and Conglomerates, usually strongly coloured with Ferric oxide, but sometimes purplish yellow or green, from the presence of Ferrous oxide. The Devonian character differs from the Silurian beds, which are very argillaceous and calcareous.

As shewn in Fig. 7, the Old Red Sandstone underlies the

FIG 7.—*Brockley Combe Section.*

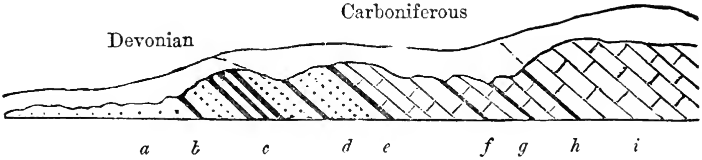


a Devonian.—*b* Lower Limestone Shales.—*c* Carboniferous Limestone.

Carboniferous, and in point of sequence intervenes and separates it from the Silurian.

In many places the junction between the Devonian and Carboniferous beds is exposed; as for instance at the side of the Avon, under Cook's Folly (Fig. 8).

FIG. 8.—*Junction of Devonian and Carboniferous at Cook's Folly.*



a Micaceous beds.—*b* Quartzose Conglomerates.—*c* Three beds of rolled Quartz pebbles—*d* Last bed of rolled Quartz.—*e* First Calcareous bed. —*f* Athyris bed.—*g* Entomostraca and plants.—*h* Modiola bed.

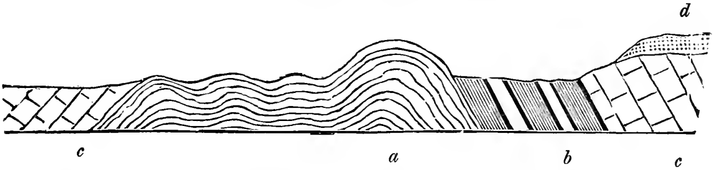
The transition from one to the other is so gradual that the cessation of the Devonian and the commencement of the Lower Limestone shales can with great difficulty be determined. In this district the Devonian rocks attain a thickness of about 4,000 feet.

The beds that are found in the Bristol Coal Field belong to what are termed the Middle Devonian. On the north side of the Bristol Channel the Devonian beds are much more developed, and differ somewhat in their lithological character. They there attain a thickness of 6,000 feet, a large proportion of which are Cornstones and shales.

On looking at the geological map of our President, the Devonian is only met with in isolated patches, where the beds are upheaved towards the earth's surface, and afterwards denuded by the action of the water. The Bristol beds are probably an equivalent of the Scottish series, as seen in Perthshire and Forfarshire.

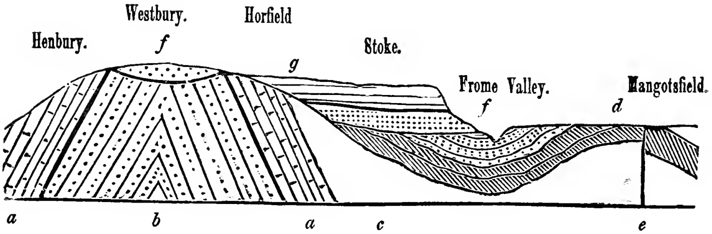
The first notice we have of the Old Red is seen resting on the Llandovery beds to the north of Tortworth. From thence it dips to the south towards the centre of the Gloucestershire Coal basin. On the east, as at Wickham, it does not come to the surface, because it is covered up by the Inferior Oolite and Lias. On the west a much larger area of Devonian is seen, reaching to Thornbury. We then lose sight of it till we reach Westbury and Shirehampton, where an extensive anticlinal ridge is thrown up, which reaches to Portbury.

Fig. 9.—*Section near Tortworth.*



a Upper Llandovery.—*b* Wenlock and Ludlow. —*c* Devonian.—*d* Trias.

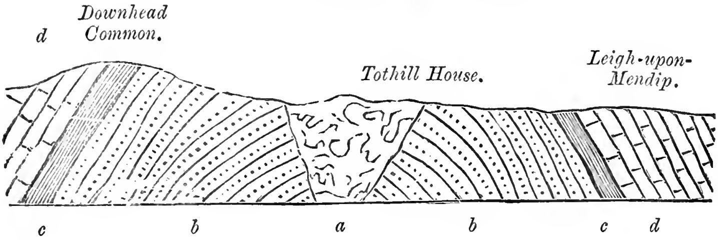
Fig 10 —*Westbury Anticlinal.*



a Carboniferous.—*b* Devonian.—*c* Lower Coal Measures.—*d* Pennant.—
e Fault.—*f* Trias.—*g* Lias.

At Portishead the beds may be seen dipping S.E., and again pointing to the centre of the Coal basin. It is, however, at the south edge of the basin that we have the greatest local developement of the Devonian beds, which attain a great altitude, forming the magnificent range of the Mendip Hills, the cause of this being a powerful upheaval of volcanic basalt.

Fig. 11.—*Section near Downhead.*



a Basalt.—*b* Devonian.—*c* Lower limestone shales.—*d* Carboniferous limestone.

The beds of Red Sandstone and Conglomerate form exceedingly good building material, which resist the weather without damage for many years. The church towers in many villages and towns in the county of Somerset are striking examples. From a small quarry on the bank of the Avon was obtained the stone with which the buttresses of the Suspension Bridge were built.

At Portishead a very good section of the Conglomerate beds may be studied on the shore near the Hotel, at Woodhill Bay. It was here that Dr. Martyn found the scales of Holoptychius, noticed for the first time in this locality. Since then remains of Coccosteus, Fucoids, &c., have been collected. Dr. Martyn gathered his specimens in a bed of Conglomerate that projects out of the beach, but the same bed has been traced to its position on the rocks, as shewn in the following list of the beds.

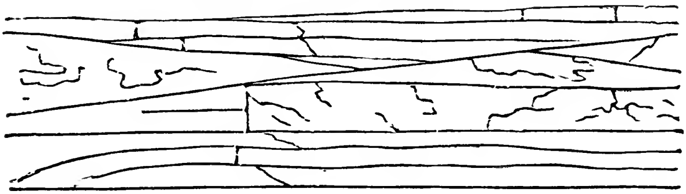
	Ft.	In.	
1.—	12	0	Red Slaty Sandstone.
2.—	2	0	Sandstone.
3.—		11	Red Marls.
4.—	8	0	Red Conglomerate.
5.—	[illegible]	0	Sandstone.
6.—	3	0	Ditto
7.—	3	0	Conglomerate passing with Limestone, containing scales of Holoptychius, &c., at top.
8.—	1	0	Sandy Marl.
9.—	1	0	Conglomerate.
10.—	8	0	Sandy Marls.
11.—	3	0	Sandstone.
12.—	14	10	Sandy Marls and fissile Sandstone.
			Shingle of Beach.

With the exception of this fish bed, there is a marked absence of fossils in the Devonian beds of this neighbourhood. From the promising aspect of the beds between Sea Mills and Cook's Folly, it is probable that they would reward a diligent search with a longer list of specimens.

In what are termed the upper Devonian beds, as seen at Marwood, Pilton, and Baggy Point, fossils are very numerous, but as the author thinks the balance of evidence is in favour of their being Carboniferous, and not Devonian, and as the chief locality is on the banks of the Avon, their consideration will be deferred until the next lecture.

Below Sea Mills the beds have been much disturbed and broken. These changes may be seen in the railway cutting at Hungroad, when the physical characters may be well studied. One remarkable instance of false bedding is shewn in fig. 12.

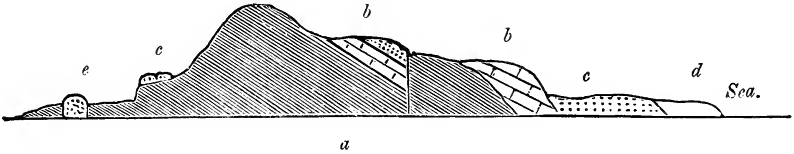
FIG. 12. *Hungroad Section, shewing irregular bedding.*



The Devonian fossil fauna indicates a marshy country, accessible to the encroachment of high tides. The comparative absence of Conchifera and other marine forms supports the opinion of Sir Charles Lyell and Professor Huxley, that the fish of the old red period inhabited a swampy region, like the banks of the Nile, Gambia, and Senegal. In those places the Polypterus abounds, which has a great resemblance to the Devonian Holoptychius, Osteolepis, Dipterus, Glyptolemus, &c. It is singular, too, that all these belong to the fringe finned fishes (Crossopterygidæ).

In the village of Portishead the Devonian beds have been broken and greatly displaced. The woodcut (fig. 13) shews this, and also a fault that has divided both the Devonian and Carboniferous rocks.

FIG. 13. *Section at Portishead.*



a Devonian.—*b* Carboniferous.—*c* Trias.—*d* Alluvium.

List of Land and Fresh-water Mollusca of the Bristol District.

BY ADOLPH LEIPNER.

IN the following list of land and fresh-water Mollusca I have entirely followed the arrangement and nomenclature of Mr. J. Gwynn Jeffreys, in his *British Conchology,* it being the most recent of the standard works upon that subject that I am acquainted with, and probably also in possession of all the Conchologists of our Society.

The list itself is, through the kindness of several friends, far more complete than it would have been without their aid; and I have to acknowledge the kind assistance of the Misses Jessie and Fanny Hele, Miss Laura C. Jones, and Miss E. C. Jelly, whose respective initials are placed after the information furnished by them. It will also be seen that I have utilized the MSS. left with me by Mr. Thomas Graham Ponton, and have had the assistance of two other members of our Society, viz., Mr. W. W. Stoddart and Mr. Edwin C. Wheeler, whose share of the work is also acknowledged by their initials. The stations observed by myself are marked thus *.

CLASS, LAMELLIBRANCHIATA.

FAMILY I.—SPHÆRIIDÆ.

Genus 1: *Sphærium*. Scopoli.

1. S. cornea, L. (Cyclas cornea. Forbes and Hanley.)
   Not uncommon throughout the district. (*) In the river at Stapleton (T. G. P. and J. & F. H.), Shirehampton (E. W.), Keynsham, Nailsea, Clevedon (J. & F. H.).

Var. i. flavescens. Macgillivray.
Clevedon (L. C. J.)

Var. ii. nucleus. Studer.
(*) Clevedon.

Var. iv. Pisidioides. Gray.
In the Avon (W. W. S.)

2. S. rivicola. Leach (Cyclas rivicola. Lamarck.)
   In the river at Stapleton (F. G. P.) 1862, (J. & F. H.) 1874; Keynsham (J. & F. H.)

3. S. ovale. Ferussac. (Cyclas ovalis. Fer.)
   Kennet Canal (W. W. S.)

4. S. lacustre. Müller. (Cyclas caliculata. Forb. and Hanl.)
   Clifton, in ponds (T. G. P.), pond near Horfield, pond on Downs, Keynsham, in stream (J. & F. H.)

Genus 2. *Pisidium*. C. Pfeiffer.

1. P. amnicum. Müller.
   In the river at Stapleton (F. G. P.) 1862, Horfield (W. W. S.), Clevedon and Nailsea (J. & F. H.)

2. P. fontinale. Draparnaud.
   Stapleton (W. W. S.)

Var. i. Henslowana. Sheppard.
Leigh Woods (E. W., J. & F. H.), Kennet Canal (W. W. S.)

Var, iii. pallida. G. Jeff.
Kennet Canal (W. W. S.)

Var. iv. cinerea. Alder.
Kennet Canal (W. W. S.)

3. P. pusillum. Gmelin.
Bedminster (W. W. S.)

Var. obtusalis. C. Pfeiffer.
Kennet Canal (W. W. S)

4. P. nitidum. Jenyns.
Horfield (W. W. S.)

FAMILY II.—UNIONIDÆ

Genus 1. *Unio.* Philipsson.
1. U. tumidus. Philipsson.
In the river at Stapleton (T. G. P., W. W. S.), Kennet Canal (W. W. S.)

Var. i. radiata G. Jeff.
Stapleton (W. W. S.), (*) Kennet Canal.

Var. ii. ovalis. Montague.
Avon (W. W. S.)

2. U. pictorum. Linné.
In the Avon at Stapleton (T. G. P.) 1863 (W. W. S.), (*) Kennet and Avon Canal (W. W. S.)

Genus 2. *Anodonta.* Lamarck.
1. A. cygnea. Linné.
In the river at Stapleton (F. G. P.) 1862 (W. W. S.), (*) Kennet and Avon Canal (W. W. S.)

2. A. anatina. Linné.
(*) Kennet and Avon Canal (W. W. S,)

Var. i. radiata. G. Jeff.

(*) Kennet and Avon Canal

Var. ii. ventricosa. C. Pfeiffer.

(*) Kennet and Avon Canal.

FAMILY III.—DREISSENIDÆ.

Genus 1. *Dreissena.* Van Beneden.

1. D. polymorpha. Pallas.

In the Docks at Bristol (T. G. P.) 1862, in the Avon, and in the (*) Kennet and Avon Canal (W. W. S.)

CLASS, GASTEROPODA.

ORDER I.—PECTINIBRANCHIATA.

FAMILY I.—NERITIDÆ.

Genus 1. *Neritina.* Lamarck.

1. N. fluviatilis. Linné.

Common throughout the district (W. W. S.), near Baptist Mills, rare; Brislington, common, (T. G. P.) 1863; (*) in the river at Stapleton, Keynsham (J. & F. H.) 1874.

FAMILY II.—PALUDINIDÆ.

Genus 1. *Paludina.* Lamarck.

2. P. vivipera. Linné.

Rare in the pond near Henbury and at Brislington (T. G. P.) 1863; one specimen in the Brick-ponds below Cook's Folly (E. C. W.), in the river at Keynsham (J. &. F. H.), (*) in the Frome (W. W. S.)

Genus 2. *Bythinia.* Gray.

1. B. tentaculata. Linné.

Rare in the ditches at Shirehampton (T. G. P.) 1864, (E. C. W.) 1874; in the river at Stapleton, stream at Clevedon, Nailsea, and Keynsham (J. & F. H.)

2. B. Leachii. Sheppard.
In the Avon (W. W. S.)

Genus 3. *Hydrobia.* Hartmann.

2. H. ventrosa. Montagu.
Shirehampton, in ditches (T. G. P.) 1864; Avon, at Cook's Folly (W. W. S.)

3. H. ulvæ.
(*) Weston-super-Mare, abundant.

FAMILY III.—VALVATIDÆ.

Genus 1. *Valvata.* Müller.

1. V. piscinalis. Müller.
In streams at Nailsea and Keynsham (J. & F. H.), at Clevedon (L. C. J.), (*) Kennet and Avon Canal (W. W. S.)

ORDER II.—PALMOBRANCHIATA. (a) AQUATIC.

FAMILY I.—LIMNÆIDÆ.

Genus 1. *Planorbis.* Guettard.

2. P. nitidus. Müller.
Shirehampton (E. C. W.), Westbury and Bedminster (W. W. S.)

3. P. nautileus. Linné.
Pond near Horfield, very sparingly (J. & F. H.); Bedminster (W. W. S.)

4. P. albus. Müller.
Near Westbury (E. C. W.), Durdham Down (W. W. S,)

6. P. spirorbis. Müller.
Durdham Down and pond at Messrs. Garraway's Gardens (E. C. J.), Stapleton (T. G. P.), Shirehampton (E. C. W.), Clevedon (L. C. J.), Horfield, (*) Westbury, Bedminster (W. W. S.)

7. P. vortex. Linné.
Shirehampton (T. G. P., E. C. W.), (*) streams near Clevedon (J. & F. H., L. C. J.), Durdham Downs (W. W. S.), (*) Weston-super-Mare.

8. P. carinatus. Müller.
(*) Common throughout the district.

9. P. complanatus. Linné. (P. marginatus. F. & H.)
Durdham Downs (E. C. J., T. G. P.), Shirehampton (E. C. W.), streams near Clevedon (J. & F. H.) 1874.

10. P corneus. Linné.
Pond near Henbury, rare (T. G. P.); streams near Clevedon (J. & F. H.) 1874; Brislington (W. W. S.)

Var. albina. Jeff.
Streams near Clevedon (J. & F. H.) 1874.

11. P. contortus. Linné.
Durdham Downs (E. C. J.), Ashton (E. C. W.), Shirehampton and Stapleton (W. W. S.), (*) Clevedon.

Genus 2. *Physa.* Lamarck.

1. P. hypnorum. Linné.
(*) Shirehampton, in ditches (T. G. P.) 1864; Ashton (E. C. W.), near Horfield (J. & F. H.) 1874.

2. P. fontinalis. Linné.
(*) Stapleton (T. G. P.) 1864, (*) Shirehampton and Ashton (E. C. W.), Clevedon (Ti G. P.), pond near Horfield (J. & F. H.) 1874.

Genus 3. *Limnæa.* Bruguierè.

1. L. glutinosa. Müller.
At Stapleton (W. W. S.)

2. L. involuta. Thompson.
Stapleton (W. W. S.)

3. L. peregra. Müller.

(*) Ponds everywhere; Shirehampton, Redland (T. G. P.) 1862; Clevedon (L. C. J.); near Westbury (J. & F. H.) 1874; Ashton (E. C. W.)

Var. iv. ovata. Drap.

Pond near Ashley Downs (J. & F. H.)

4. L. auricularia. Linné.

Messrs. Garraways's Gardens, rare (T. G. P.) 1862; In the river at Keynsham (J. & F. H.) 1874; river at Stapleton (E. C. J.), Burnham (W. W. S.)

5. L. stagnalis. Linné,

Messrs. Garraway's Gardens (T. G. P.) 1862; pond in Leigh Woods, (*) Shirehampton, Boiling Wells (E. C. W.), in the river at Keynsham, stream at Clevedon (J. & F. H.) 1874.

Var. iii. labiata. Jeff.

Clevedon (J. & F. H.)

6. L. palustris. Müller.

Messrs. Garraway's Gardens, rare (T. G. P.) 1862; river at Stapleton (E. C. J.), Clevedon (L. C. J.), Ashton (E. C. W.)

Var. v. rosea-labiata. Jeff.

Clevedon (J. & F. H.)

7. L. truncatula. Müller.

Horfield, rare (T. G. P.) 1858; pond at Mesrs. Garraway's (E. C. J.), near Westbury (J. & F. H.) 1874.

8. L. glabra. Müller.

Redland (W. W. S.)

Genus 4. *Ancylus.* Geoffrey.

1. A. fluviatilis. Müller.

(*) In the river at Stapleton (T. G. P.) 1872; Ashton (E. C. W.), Clevedon (L. C. J.), stream at Nailsea (J. & F. H.) 1874.

2. A. lacustris. Linné.
In the river at Stapleton, rare (T. G. P.) 1864.

Genus 5. *Assiminea.*

1. A. Grayana. Leach.
(*) Avonmouth ditches.

(b) TERRESTRIAL PULMOBRANCHIATA.

FAMILY I.—LIMACIDÆ.

Genus 1. *Arion.* Férussac.

1. A. ater. Linné. (A. Empiricorum. F. & H.)
(*) Gardens and hedges, common; (*) Durdham Downs (E. C. J.), (*) Leigh Woods.

Var. flavus. Fér.
(*) Leigh Woods, (*) Weston-super-Mare.

2. A. hortensis. Férussac.
(*) Too common in our gardens; Clevedon (L. C. J.)

Genus 3. *Limax.* Linné.

2. L. marginatus. Müller. (L. Sowerbii. F. & H.)
(*) Everywhere in gardens.

3. L. flavus. Linné.
(*) Everywhere in gardens.

4. L. agrestis. Linné.
(*) Everywhere in gardens.

6. L. maximus. (L. cinereus. F. & H.)
(*) Redland Common (T. G. P.) 1864; (*) gardens in Clifton (L. C. J.)

FAMILY. II—TESTACELLIDÆ.

Genus 1. *Testacella.* Cuvier.

1. T. Haliotidea. Draparnaud.
Kingsdown Parade (W. W. S.), Clifton gardens (L. C. J,), (*) Hampton Park, rare.

Var. scutulum. Sowerby.

Gardens at Clifton and Leigh Woods, rare (T. G. P.) 1862.

2. T. Maugei. Férussac.

(*) Hampton Park, common; Messrs. Garraway's Gardens, rare (T. G. P.) 1862; Kingsdown (W. W. S.)

Family III.—Helicidæ.

Genus 1. *Succinea.* Draparnaud.

1. S. putris. Linné.

(*) Ponds everywhere (E. C. J.); Shirehampton, in ditches; ponds at Brislington (T. G. P.) 1862; Ashton, Boiling Wells (E. C. W., J. & F. H.)

2. S. elegans. Risso.

Near Westbury (J. & F. H.) 1874, Clevedon (L. C. J.), Burnham (W. W. S.)

3. S. oblonga. Draparnaud.

Burnham (W. W. S.)

Genus 2. *Vitrina.* Draparnaud.

1. V. pellucida. Müller.

(*) Durdham Down (E. C. W.), (*) Coomb Dingle (E. C. J.), near Sea Mills (J. & F. H.) 1874, Stapleton (W. W. S.), Clevedon (L. C. J.)

Genus 3. *Zonites.* De Montfort.

1. Z. cellarius. Müller.

(*) Common in the gardens of Clifton and Redland, Richmond Hill (E. C. W.), (*) Durdham Downs (J. & F. H.) 1874, (*) Leigh Woods, Stapleton (W. W. S.)

Var. ii. albida. Jeff.

Near Clifton (J. & F. H.) 1874.

2. Z. alliarius. Müller.

Stapleton, on walls (T. G. P.); (*) Leigh Woods, Coomb Glen (E. C. W,), Clifton gardens (L. C. J.); Parry's Lane (J. & F. H.) 1874; (*) Messrs. Garraway's Gardens, Stapleton, Ashton (W. W. S.)

3. Z. nitidulus. Draparnaud.

(*) Under stones at Coomb Glen, (*) Leigh Woods, Failand, etc. (E. C. W.); near Sea Mills (L. C. J.), near Ashley Downs (J. & F. H.) 1874; (*) Durdham Downs (E, C. J.

4. Z. purus. Alder.

Leigh Woods (E. C. W.), in moss from Coomb, etc. (E. C. J.), near Clifton (J. & F. H.) 1875.

Var. margaritacea. Jeff.

Near Clifton (J. & F. H.) 1874.

5. Z. radiatulus. Alder.

(*) Everywhere (E. C. J.)

6. Z. nitidus. Müller.

Boiling Wells (E. C. W.)

8. Z. crystallinus. Müller.

Stapleton, on walls (T. G. P.), in moss from Coombe (E. C. J.), near Clifton (J. & F. H.), 1874, Ashley Brook (*) Leigh Woods, Ashton (W. W. S.)

Var. complanata.

Found by Mr. Gwyn Jeffreys in Leigh Woods.

9. Z. fulvus. Muller. (Helix fulva. Muller.)

Stapleton, under stones (T. G. P.), Leigh Woods, Cook's Folly, Horfield (W.W.S.)

Genus 4. *Helix*. Linné.

2. H. aculeata. Müller.

Under stones at Stapleton (T. G. P.), sparingly among moss from Coombe (E. C. J.)

4. H. aspersa. Müller.
(*) Common everywhere, in gardens and hedges.

Var. i. albo-fasciata. Jeff.
Near Westbury (J. & F. H.), 1874.

Var. ii. exalbida. Menke.
Near Westbury (J. & F. H.), 1374.

Var. iii. conoidea. Picard.
Occasionally in hedges (J. & F. H.), 1874.

5. H. nemoralis. Linné.
(*) Hedges and fields everywhere.

Var. i. hortensis. Müller.
(*) Hedges and fields, but not so common.

Var. ii. hybrida. Poiret.
Bitton (J. & F. H.), 1874.

Var. iii. major. Ferussac.
Parry's Lane (J. & F. H.), 1874.

Var. iv. minor. Jeff.
Parry's Lane (J. & F. H.), 1874.

6. H. arbustorum. Linné.
Gardens (T. G. P.), 1861, Leigh Woods, Clifton Downs (E. C. W.), (*) near Stapleton (J. & F. H.), 1874.

7. H. cantiana. Montagu.
Cook's Folly, Leigh Woods (T. G. P.), 1863, Ashton, (*) river banks (E. C. W., E. C. J.), river banks, near Ashley Downs (J. & F. H.), 1874, Bishopsworth W. W. S.)

9. H. rufescens. Pennant.
(*) Hedges, common (T. G., P., E. C. W.), Stoke Bishop (L. C. J.)

Var. i. Albida, Jeff.
Occasionally in hedges at Westbury, &c. (J. & F. H.), 1873, Stoke Bishop (L. C. J.)

Var. 2. minor. Jeff.
Parry's lane (J. & F. H.), 1874, near Sea Mills (L. C. J.)

10. H. concinna. Jeff.
Near Coomb Downs (J. & F. H.), 1874; under stones on Durdham Downs (E. C. J.)

Var. i. albida. Jeff.
Under stones on Durdham Downs (E. C. J.)

Var. ii. Minor. Jeff.
Near Sea Mills (L. C. J.)

11. H. hispida. Linné.
(*) Under stones in Quarries by the river and on the Downs (T. G. P.), 1863, (E. C. W.) 1874; Leigh Woods, Coomb Glen (E. C. W.); common everywhere (W. W. S.)

Var. ii. albida. Jeff.
Near Ashley Downs (J. & F. H.), 1874.

12. H. sericea. Müller.
Near Mr Müller's Orphan Houses, rare (T. G. P.), 1863; Boiling Wells (E. C. W., J. & F. H.)

14. H. fusca. Montagu.
Stapleton, under stones (T. G. P.); Leigh Woods, Cook's Folly (W. W. T.); near Bristol (F. H.) 1874.

16. H. virgata. Da Costa.
(*) Common everywhere, Clifton and Durdham Downs, river banks (E. C. W., J. & F. H., E. C. J.)

Var. ii. subglobosa. Jeff.
Clifton Downs (L. C. J.)

17. H. caperata. Montagu.
(*) Nearly everywhere, (*) the Downs, near Cook's Folly (T. G. P.), 1863 (J. & F. H.); Cliffs near the river (J. & F. H.), (*) under stones on Durdham Downs (E. C. J.)

Var. ii. major. Jeff.
Near Redland (J. & F. H.), 1874.

Var. ii. ornata. Jeff.
Quarry on the Downs (J. & F. H.)

Var. iii. subscalaris. Jeff.
Near Redland (J. & F. H.), Clifton Downs (L. C. J.)

18. H. ericetorum. Müller.
(*) Downs (F. G. P.) 1869, (E. C. W.)

Var. ii. minor. Jeff.
St. Vincent's Rocks (F. & J. H.)

19. H. rotundata. Müller.
(*) Common nearly everywhere, in gardens (T. G. P.) 1864; Old Wells near Westbury (J. & F. H.), Combe Dingle (E. C. J.)

Var. iii. Turtoni. Fleming.
Found by Mr. Gwyn Jeffreys, in Bristol, Clevedon (L. C. J.)

20. H. rupestris. Studer. (H. umbilicata. F. & H.)
Downs, on limestone rocks (T. G. P.) 1862; (*) St. Vincent's Rocks, Sea Mills, old wall in Paddy's lane (E. C. W., J. & F. H.), (*) abundant on walls, Redland (E. C. J.)

Var. viridescenti-alba. Jeff.
Found by Mr. Webster at Clifton (Jeffrey's *British Conch.*, vol. 1, p. 221).

21. H. pygmæa. Draparnaud.

On walls at Redland (F. G. P.), 1864; (*) Quarries on the Downs (E. C. W.), old walls near Westbury (J. & F. H.)

22. pulchella. Müller.

On walls at Redland (T. G. P.), 1859; Cook's Folly, Sea Mills, banks of the river (E. C. W.), (*) Durdham Downs (J. & F. H.), abundant in moss everywhere (E. C. J.)

Var. costata. Müller.

Near Westbury (J. & F. H.)

23. lapicida. Linné.

(*) In gardens, common, St. Vincent's Rocks, Leigh (E. C. W.), Parry's Lane (J. & F. H,); in the crevices of the rocks just beneath the Observatory (E. C. J.)

Genus 5. *Bulimus*. Scopoli.

1. B. acutus. Müller.

Downs. under stones (T. G. P.), 1863; (*) Leigh Woods (W. W. S.)

3. B. obscurus. Müller.

(*) Everywhere (W. W. S.), Downs, under stones (F. G. P.), 1893, (E. C. W.), Ashton (E. C. W.), St. Vincent's Rocks (J. & F. H.), 1873, rocks, Hotwell Road (E. C. J.)

Var. alba. Jeff.

St. Vincent's Rocks (J. & F. H.)

Genus 6. *Pupa*. Lamarck.

1. P. secale. Draparnaud.

(*) Downs, under stones (T. G. P.), 1862, (*) St. Vincent's Rocks, abundant (E. C. W., J. & F. H.), (*) Rocks, Hotwell Road, E. C. J.)

Var. alba. Jeff.
St. Vincent's Rocks (J. & F. H.)

3. P. umbilicata. Draparnaud.
(*) Everywhere (E. C. J.), (*) Hotwell Road, near Clifton Downs (T. G. P.), Old Wells, near Westbury (J. & F. H.)

4. P. marginata. Draparnaud. (P. muscorum. F. & H.)
E. C. W.), Quarry land, near Redland (J. & F. H.), (*) Downs, under stones (T. G. P.), 1862, Sea Mills.

Genus 7. *Vertigo.* Müller.

1. V. antivertigo. Draparnaud.
Downs, under stones (T. G. P.), 1862, Boiling Wells (W. W. S.)

3. V. pygmæa. Draparnaud.
Downs, under stones, (T. G. P.), 1862, Quarry land, near Redland (J. & F.)

9. V. minutissima. Hartmann.
Stapleton (T. G. P.), 1864, Frome Glen, (W. W. S.)

Genus 8. *Balia.* Prideaux.

1. B. perversa. Linné. (B. fragilis. F. & H.)
Old oak trees at Ashton and Sea Mills (E. C. W.), old wells near Westbury (J. & F. H.)

Genus 9. *Clausilia.* Draparnaud.

1, C. rugosa. Draparnaud. C. nigricans. (F. & H.)
(*) Common everywhere, (*)Leigh Woods, (*) Sea Mills, (*) Downs (E. C. W., J. & F. H., E. C. J.)

Var. ii. Everetti. Müller.
Found by Müller. (See G. Jeffrey's *British Conch.*, vol. 1, p. 279.)

Var. iv. tumidula. Jeff.
Occasionally on old walls, &c., Westbury (J. & F. H.), Stoke Bishop (L. C. J.)

2. C. Rolphii. Gray. (C. plicatula. F. & H.)
Ashton, Buttress of Suspension Bridge (W. W. S.)

3. C. biplicata. Montagu.
Downs (T. G. S.) 1862, Leigh Woods, Oldbury Combe (W. W. S.)

4. C. laminata. Montagu.
(*) Leigh Woods, (*) New Road near former Clifton Turnpike (E. C. W., J. & F. H.) 1874.

Var. i. pellucida. Jeff.
Near Stoke (J. & F. H.)

Var. ii. albida. Jeff.
Leigh Woods (J. & F. H.), Clifton Downs (L. C. J.)

Genus 10. *Cochlicopa.* Ferussac.
1. C. tridens. Pulteney (Azeca tridens, F. & H.)
Var. crystallina. Dupuy.
Brockley Combe (see G. Jeffrey's *British Conch.* Vol. I. p. 291.)

2. C. lubrica. Müller (Zua lubrica. F. & H.)
(*) Abundant everywhere among moss. (*) Downs, (T. G. P., J. & F. H.), (*) Coombe Dingle (E. C. J.)

Genus 2. *Achatina. Lamarck.*
1. A. acicula. Müller.
Downs (T. G. P.) 1862, Durdham Downs, dead shells (J. & F. H.) 1874, Leigh Woods, Oldbury Court Woods (W. W. S.)

FAMILY IV.—CARYCHIIDÆ.

Genus 1. *Carychium.* Müller.
1. C. mininum. Müller.
Near the Lighthouse, rare (F. G. P.) 1963, Durdham Downs (J. & F. H.), Avon, (*) near Cook's Folly (W. W. S.)

Genus 2. *Conovulus.*

1. C. denticulatus. Montagu.

Shirehampton, in mud (T. G. P.) 1864, Sea Mills and Shirehampton (J. & F. H.), Cook's Folly (W. W. S.)

3. C. bidentatus. Montagu.

Var. alba. Turton.

Sea Mills (J. & F. H.) 1874.

FAMILY V. CYCLOSTOMATIDÆ.

Genus 1. *Cyclostoma.* Draparnaud.

1. C. elegans. Müller.

(*) St. Vincent's Rocks, (*) Hedges near Sea Mills (J. & F. H.), (*) Downs on limestone rocks (T. G. P.) 1861, (*) Hotwell New Road (E. C. J.)

Genus 2. *Acme.* Hartmann.

1. A. lineata. Draparnaud.

Amongst damp grass and moss on Downs, and at Shirehampton (T. G. P.) 1862.

Var i. alba. Jeff.

Rejectamenta of the river Avon, at Bristol (see G. Jeffrey's *British Conch.* Vol. I, p. 309.

Var. ii. sinistrorsa. Jeff.

A single specimen among the refuse of the Avon at Bristol (see J. G. Jeffrey's *British Conch.* Vol. I, p. 309.

Notes on Bristol Fungi.

BY C. E. BROOME, F.L.S.

IN the *Flora Bristoliensis*, by Mr. Swete, published in 1854, a radius of five miles from the city of Bristol as a centre, was adopted as a convenient arrangement, both as regards the geology of the district and the distribution of the plants upon its surface, and we cannot do better than follow his steps generally, as we thus keep within a distance not too extended for a ramble in search of Fungi. The connection of the flowering plants with the kind of rock on which they grow is manifest, and although Fungi do not depend to such an extent on the nature of the soil as on the amount of warmth and moisture—resulting from the presence of woods and sheltered spots, and the kind of trees and shrubs with which the earth is clothed,—yet, as the latter depend, in some measure, on the geological character of the soil, an indirect connection is maintained between the geology and the mycology of a given surface But, besides this, a more immediate cause for a rich mycological flora arises from the varied composition of the rocks around Bristol, and the great amount of their dislocation and upheaval. We find the surface of the district broken up into deep gullies, whose sides are richly clothed with vegetation, and a moist atmosphere thus engendered and retained, and hence a copious mycology might reasonably be expected.

Bristol may not boast, perhaps, so numerous a list of the higher tribes of Fungi as other localities which possess more extensive tracts of forest, and which have been investigated by botanists well read in the recent sub-divisions of the older species, such as Epping Forest, or the extensive heaths and ancient forests of Scotland, but it produces, nevertheless, a sufficient number of rare and beautiful forms to render it very interesting to the mycologist, especially to such as look further than for outward beauty, and can admire minute structure and microscopic detail. In illustration of the nature of the district around Bristol, we may instance Nightingale Valley, and the adjacent Down, and Leigh Wood, on the mountain-limestone, which afford some of the best spots for the mycologist. The locality marked in Swete's plan of the physical aspects of the district as "the lesser or Western Plateau," and its range, continuing on to Clevedon, will reward the pedestrian with a charming view over the Bristol Channel to the Monmouthshire hills on the north, and glimpses of the rich plains of Somersetshire to the south. Among its mycological treasures we may mention the beautiful *Agaricus (Russula) auratus*, Fr., in Leigh Wood; several species of the tribe *Amanita*, the rare *Agaricus Loveianus*, B., which grows parasitically on *Agaricus nebularis*, Batsch., discovered by Mr. H. O. Stephens, in Leigh Wood; the rare truffle, *Hydnangium carotæcolor*, B., also found by the same botanist growing in Leigh Wood, and resembling little bits of carrot, hence easily recognised by its colour, as it lies among the ivy and low herbage. Another rarity, *Octaviania Stephensii*, Tulasne, so named in honour of its discoverer, may be found concealed beneath the dead leaves of Tilia parvifolia in parts of Leigh Wood, the only other locality known for it being the Lime woods near Naish House, Wraxall. This truffle is remarkable for its white milk, which runs out when the plant is cut. *Tuber excavatum*, Vitt., and *T. puberulum*, B., occur also in Leigh Wood; *Polyporus Stephensii*, B., grows on dead twigs of Privet in the same locality; the rare *Dædalea confragosa*, P., used to grow on trees on Leigh Down, where numerous other species occur, the fine *Clavaria pistillaris*, L., and *C. Ardenia*, Sow., among them.

On Swete's Northern Plateau *Agaricus (Hygrophorus) leporinus*, Fr., used to occur, and proceeding northwards at Stoke House, Druid Stoke, *Tuber macrosporum*, Vitt., occurred first for Great Britain, near which place *Stephensia bombycina*, Tul., used to grow in tolerable abundance, being named after the botanist before alluded to by M. Tulasne. A strip of Old Red Sandstone runs up near this spot from the river, and on it some Hypogæous fungi used to occur; others were found in the plantations belonging to Kingsweston Park. The botanist may enjoy a bit of beautiful scenery by prolonging his walk in this direction to Penpole Point; and should he add a love of Algæ to his other tastes, some very interesting forms may be met with in the brackish ditches near the Lighthouse. The "Pennant Plateau" to the north-west may be traversed with advantage: it extends to Stapleton, and is separated from the Northern Plateau by the valley of the Frome. Along the side of this little river a path leads to some very picturesque scenery below the village of Stapleton—the mill and its weir clothed with the larger coltsfoot, the bold sandstone rocks, and some beautiful silvery willow trees—seldom allowed to attain their full size—used to render this a favourite spot for artists. Under Bryum hornum on the rock a curious little fungus may be met with, *Cenococcum geophilum*: it resembles small shot, but has never yet been found with perfect fruit. If the botanist returns through Stapleton Grove he may find some rarities there—the elegant *Agaricus mucidus*, Fr., is seen at times on the stems of the beech trees; rare Hypogæi occur under the dead leaves, *e.g.*, *Genea verrucosa*, Vitt., *Hydnobolites cerebriformis*, Tul., and two or three species of *Tuber*, *Hymenogaster*, &c. In a narrow plantation in Stoke Park the rare *Sistotrema confluens* once occurred.

Another excursion may be mentioned which will reward the mycologist if he be in luck. It is to the wood on the Pennant rock, extending from Hanham to Conham on the Avon. The train may be taken to Keynsham, whence a short walk leads to the Hanham ferry, and about half a mile further, on returning towards Bristol, the ground to be searched commences by some heathy spots and old quarries. Several of the red *Pezizæ* occur on the slopes; on the wet sides of the quarries some good Algæ, such as Cosmaria, occur; on the flat heath above the curious little *Marasmius impudicus*, Fr., may be found,—where also the beautiful *Agaricus (Hygrophorus) calyptræformis*, B., used to be plentiful, but the habitat has been almost destroyed to grow potatoes, an attempt which seems to be a failure, as the ground is returning to its former condition; in the woods further on the rare *Strobylomyces strobilaceus*, B., was found, two or three years ago, on a spot which had been searched over by mycologists for many years, but this fungus had never been seen there before. This fact shows the difficulty of ascertaining the extent of the mycological flora of a neighbourhood. The exceptional appearance of a species, however, holds out hopes to the cryptogamic botanist of alighting on new forms when least expected, which can hardly occur to those who confine their attention to the higher vegetables.

Hanham Woods have yielded several rarities among the more obscure tribes, *Pachyphlœus citrinus*, B., *P. conglomeratus*, B., the only habitat known in Great Britain; *Sphærosoma ostiolatum*, Kl., *Genea hispidula*, B., *Tuber puberulum*, B, often infested with the parasitic *Hypocrea inclusa*, Br., *Tuber dryophilum*, Tul., and *Boletus parsiticus*, Bull., may be mentioned among the rarities. Having thus pointed out some of the best excursions for the mycologist, we will now present a short list of the species which have been met with and determined in the district.

Mr. H. O. Stephens was, perhaps, the first person who paid much attention to the mycology of the neighbourhood of Bristol, but he laboured under so many disadvantages in regard to the literature of the subject and the absence of a herbarium, which is indispensible to the correct determination of the species of several genera, such as Polyporus, that great credit is due to him for the work he accomplished. In the *Annals of Natural History* for the year 1840 he recorded about forty species of Agaricini: among the rarer forms were *Agaricus adiposus*, Batsch, and *A. Loveianus*, B., two *Cantharelli*, three *Boleti*, four *Polypori*, one *Radulum*, four *Thelephoræ*, two *Clavariæ*, one *Geoglossum*, two *Helvellæ*, seven *Pezizæ*, one *Tremella*, the unique species of *Sphærobolus*, eight *Sphæriæ*, among which was the rare and curious *S. entomorrhizæ*, which grows on caterpillars, after they have buried themselves in the earth, to undergo their first transformation, *Geaster rufescens*, a rare species of the puff-ball tribe, three species of *Myxogaster*, one mould *Sepedonium*, and fifteen species of leaf fungi, *Puccinia*, *Æcidiæ*, &c.—in all, about ninety-six species. In 1848 Mr. Stephens published a supplementary list of forty species, with some corrections of the nomenclature in his former list, which the acquisition of Fries' system and Sowerby's figures enabled him to make; subsequently he discovered some of the rarities before spoken of, *Hydnangium carotæcolor*, B., and *Octaviania Stephensii*, T. After that he contributed numerous species to the papers published by Messrs. Berkeley and Broome, in the *Annals of Natural History*.

The next botanist who took up the mycology of the neighbourhood of Bristol, although better known at that time as an Algologist, was Dr. Thwaites, the present Curator of the Royal Botanic Garden at Pergadenia, Ceylon, and author of a Flora of that country. His contributions to the Fungi of Bristol were also included in the papers in the *Annals of Natural History*. The name of the Rev. W. R Crotch must not be omitted from the list of Bristol mycologists. Although residing beyond our prescribed limits, he visited the choicer localities within them from time to time, and published the results in the Proceedings of the *Somersetshire Archæological and Natural History Society* for 1852. In Mr. Crotch's list, 270 species of Agaricini are recorded out of

699 in Cooke's Handbook; many of the latter are critical species, separated off from the older forms by the closer scrutiny of modern writers. Among the rarer species in Mr. Crotch's list are *Agaricus sejunctus*, Sow., Leigh Woods; *A. acute-squamosus*, Fr., one of the most elegant of fungi, Leigh Woods; and *A. mucidus*, Schr., Leigh Wood and Stapleton Grove; *A. platyphyllus* Fr., and *A. pelianthinus*, Fr., Leigh Wood; *A. ionides*, Bull, *A. giganteus*, Sow., *A. hæmatopus* P.. *A. porrigens*, P., *A. Loveianus*, B., *A. chrysophans*, Sch., *A. phlebophorus*, Dittm., *A. plumosus*, Bolt, *A. violaceus*, L. (*Cortinarius violaceus*, Fr.), a magnificent species; *A. chrysodon*, Batsch, remarkable for its golden edge; *A. olivaceo-albus*, Fr., and *A. leporinus*, Fr., *A. turpis* Fr. (now *Lactarius turpis*), *A. Xerampelina*, *F.* and *A. auratus*, Fr. (now *Russulæ*), *Cantharellus cinereus*, P., *Marasmius fusco-purpureus*, Fr., *M. archyropus*, Fr., *M. calopus*, P., *M. Vaillantii*, Fr., *M. fœtidus*, Sow., *Boletus edulis*, Bull, which makes an excellent dish at Fungus feasts; *B. parasiticus*, Bull, *Polyporus perennis*, L., *P. brumalis*, Fr., *P. nummularius*, Fr., *P. Stephensii*, B. and Br., *P. obducens*, Fr., Failand; *Dœdalea confragosa*, Bolt. *Fistulina hepatica*, Bull; also a capital subject for the cuisine—all these were found in Leigh Wood, 44 species of Polyporei being contained in Mr. Crotch's list out of 141 British in Cooke's work. Eleven Hydnei are mentioned in Crotch's list out of 42 British, *Irpex fusco-violaceus*, Fr., and *Sistotrema confluens*, P., being among the rarer forms.

Of Auricularini Mr. Crotch gives 30 out of 71 British. The most worthy of remark are *Craterellus lutescens*, Fr., *C. sinuosus*, Fr., *Thelephora cæsia*. P., *T. fastidiosa*, Fr., *Cyphella lacera*, Fr., and *Corticium cœruleum*, one of the most beautiful of Fungi.

In Clavariei, *Clavaria Botrytis*, P., *C. Ardenia*, Sow., *C. pistillaris*, L., and *C. glossoides*, Fr., with *Geoglossum viride*, Sch., which is wrongfully placed here, are, perhaps, the most interesting forms in this order, of which 22 out of 54 British belong to the district.

Of Tremellini, 7 only out of 31 recorded in Cooke's Handbook are noted, *Tremella terrestris*, B., being new. This order is interesting from its various forms of fruit and its doubtful affinities. It has been beautifully illustrated by M. Tulasne in a paper in the *Annales des Sciences Naturelles.*

Of the naked-spored Hypogæous fungi, 12 belong to Crotch's list out of 18 in Cooke, all of which were new to Britain at that time, and 5 found only in the Bristol district.

Of Phalloidei, *Phallus impudicus*, L., and *Cynophallus caninus*, Fr., occur in Leigh Wood. There are only 4 British species in Cooke's list. These plants are remarkable for an odour resembling that of carrion: the former may be traced for many yards by this means.

Of the Trichogasters or Puff-balls, Crotch gives 8 out of 27 British. The little order Nidulariacei is represented in our district by 4 out of 6 British species.

Of Myxogasters we have 10 only recorded out of more than 100 in Cooke's book, the paucity arising, probably, more from the difficulty of determining species than from any dearth of them in the locality. For a like reason in the order Sphæronemei we find 16 species only out of 180 described in Cooke. In this order some long genera were left undescribed from want of means of discrimination, as was the case with the genus *Septoria.* Tulasne has demonstrated that many species of the order are merely different forms of other genera; thus he considers *Septoria princeps* B. and Br. as a stylosporous (naked-spored) state of *Massaria eburnea*, Tul., the former belonging to the Spæronemei, the latter to the Sphæriacei.

Of the order Melanconiei and Torulacei we find about 22 out of 69 of Cooke's list. Of fungi growing on living leaves, as *Puccinia*, *Æcidium*, and allied genera, Crotch gives about 12 species only out of 182 of Cooke, but of late almost every plant is regarded as tenanted by a distinct parasitic species, a view which must remain open to great doubt, as in many cases the only discernible difference is the fact of their inhabiting different flowering plants.

The family Hyphomycetes has been very little attended to by Bristol botanists, as is testified by the number of species claimed, 3 or 4 only out of about 260 of Cooke.

In the ascigerous group of fungi the Bristol botanists have more to show. Of the primary division, Elvellacei, and the genus *Morchella*, one only is found in Crotch's list, the edible morel. A marked form used to grow in the grounds of Blaize Castle, but scarcely specifically distinct. *Spathularia* has a single species; two *Helvellæ* are recorded in Leigh Wood; one *Leotia*, three *Geoglossæ*. Of the genus *Peziza*—of which 198 species are described in Cooke's work—26 only are given in Crotch's paper. The greater number of the genus are minute and difficult of determination, as there are few authentic specimens in existence, and to this we must attribute the paucity of species in the Bristol list. Of the other genera of the order only 5 species are mentioned out of 72 of Cooke.

Of ascigerous Hypogei in the genus *Tuber*, 8 are named in Crotch out of 10 by Cooke; of other genera of the order 6, to 16 of Cook.

Of the extensive order Sphœriacei, about 70 are recorded for Bristol in the old genus *Sphæria* alone, while Cooke gives about 487, which have been divided into numerous genera of late years, every writer creating new genera out of the old genus *Sphæria* just as the fit seizes him. Four or five other genera complete Mr. Crotch's list.

It is evident from the numbers represented in the latter, compared with those of Mr. Cooke, that much requires to be done in the Bristol district, especially in the more minute and obscure genera, in order to have a fair representation of its mycology. A work of this kind can only be achieved by those resident on the spot; and to do it successfully those who take it in hand would require the assistance of a good library and an herbarium for comparison, as no plates or descriptive works can compensate for the absence of the latter. One of the first aims of the student should be the acquisition of dried specimens of all those fungi which retain their characters in that state. With exception of the fleshy Agarics, nearly all the orders may thus be rendered available, and even in their case a negative evidence is often to be obtained, if not that of a positive kind. An abundant source of amusement and inducement for rural excursions presents itself for ladies or gentlemen, free from the toils of business, in this department of botany, and to such as are skilful in the use of the brush, the Agarics present endless objects of delineation.

Rain-fall at Clifton in 1874.

BY GEORGE F. BURDER, M.D., F.M.S.

TABLE OF RAIN-FALL.

—	1874.	Average of 20 Years.	Departure from Average.	Wet and Dry Periods.
	Inches.	Inches.	Inches.	Inches.
January	3·927	3·291	+ 0·636	+ 1·072
February	2·399	1·984	+ 0·415	
March	2·144	2·123	+ 0·021	
April	1·988	2·035	— 0·047	—4·503
May	0·663	2·424	— 1·761	
June	1·061	2·658	— 1·597	
July	1·558	2·656	— 1·098	
August	4·637	3·250	+ 1·387	+ 6·631
September ...	7·071	3·127	+ 3·944	
October	3·825	3·499	+ 0·326	
November ...	2·358	2·351	+ 0·007	
December ...	3·617	2·650	+ 0·967	
Year.	35·248	32·048	+ 3·200	

Remarks.—By the above table it will be seen that the rain-fall of the entire year exceeded the average by more than three inches. It was, however, so unequally distributed as to admit of a drought of some severity prevailing during the spring and early summer months. The last column in the table indicates the periods into which the months naturally group themselves with reference to their dryness or wetness. January, February, and March were months in which the rain-fall exceeded the average, the aggregate excess being a little more than an inch. Then came a period of deficiency, extending from April to July. In each of these four months the fall was deficient, and the deficiency for the whole period was four and a half inches. The chief intensity of the drought was from the 16th of April to the 22nd of June, in which interval of nearly ten weeks the rain-fall amounted to no more than 0·687 inch. With the month of August commenced a second period of excess, and this continued to the end of the year, the total excess of the last five months being more than six and a half inches. The excess was trifling in November, but was extremely large in September, this month yielding over seven inches of rain, and ranking as fourth in the order of the wettest months that have occurred in twenty-two years.

Specially heavy rains were noted on the 6th of October, 1·138 inch in twenty-four hours; and on the 8th of December, 1·255 inch in thirty-six hours.

The deepest snow of the year occurred on the 30th of December, when the average depth was four inches.

Reports of Meetings.

GENERAL.

Jan. 1st, 1874. The first evening Meeting of the Society was held on New Year's Day, at the Bristol Museum and Library, at 8 p.m.

The Secretary, Mr. Leipner, gave a lecture on "Mosses and their Allies." It was pointed out that winter, when flowering plants are scarce, is just the time for finding these humbler plants in their most interesting condition. Mosses, as understood in English, contain three distinct types of plants: (i.) True Mosses, or Musci; (ii.) Bog-Mosses, or Sphagnaceœ; (iii.) Liver-worts, or Hepaticœ. The lecturer remarked that he has gathered forty species of mosses in fruit in a single afternoon in Leigh Woods, and, as mentioned in a former number of the "Proceedings," had catalogued over 200 from there. The second tribe are found in bogs, and perhaps the Moors round Glastonbury were the nearest locality for them. The third group, Liver-worts, were found pretty much everywhere on damp walls, trees, &c. They differ from the mosses in their fruit; the structure of the fruit in both tribes was explained,—a moss-capule, with its lid and teeth, on the one hand, and the fruit of Marchantia polymorpha on the other hand.

In the discussion which ensued, Dr. Inman made some remarks on the various mechanical contrivances seen in plants for scattering the seeds when mature. He instanced the Touch-me-not, the spirting cucumber, the spines of the burdock, the pappus of the dandelion, &c.

The two charts of Fungi, by Worthington Smith, were exhibited to the members present.

Feb. 5th, 1874. The first paper read at the second evening Meeting was "On Fish Remains in the Bristol Old Red Sandstone," by Dr. S. Martyn. In the discussion which followed Mr. E. Tawney remarked that he had, independently of Dr. Martyn's researches, found pieces of abraded bone on two occasions, in the upper railway cutting, at the distances of six and fourteen feet respectively from the top of the highest quartz conglomerate.

The second, "Notes on *Ceratodus Forsteri*," by Mr. W. W. Stoddart, F.G.S. This paper was illustrated by a mounted specimen from Queensland, and by a half-skull with teeth, which the author had most generously purchased to present to the Bristol Museum.

March 3rd, 1874. The third evening Meeting was occupied with a lecture by Mr. Benjamin Lobbe, entitled "Dartmoor Memories," illustrated by sketches and specimens of the Flora of the District.

April 2nd, 1874. On the fourth evening Meeting Dr. Inman gave a lecture "On the feet of Insects," illustrated by skilful black-board sketches.

Mr. T. Pease exhibited live specimens of Testacella. There is one species naturalized in Clifton which was introduced with plants from Madeira into Garraway's Nursery garden.

May 7th, 1874. Annual Meeting. Mr. W. Sanders, F.R.S., was re-elected President. The Vice-Presidents and Officers were also re-elected. Three new Members of Committee, viz., Messrs. C. Hudson, J. E. Jose, and F. J. Fry, were elected in lieu of those retiring by rotation. The Report of the Council was read and adopted.

October 1st, 1874. After the summer recess, the first evening meeting, being the sixth of the year, was occupied with a lecture by Mr. W. Lant Carpenter, B.Sc., "On the Physical Theory of Under-currents, and of Oceanic circulation generally, with some account of H.M.S. *Challenger*."

November 3rd, 1874. At the seventh evening Meeting Dr. C. Hudson gave a lecture on "Bristol Rotifers, their haunts and habits." Some remarks on their classification were first made, of which a report appears above, and then the lecturer passed on to describe a few types, which were most effectively shown by large coloured diagrams illuminated as transparencies. Among those exhibited in this way were *Stephanoceros*, *Floscularia*, *Œlcistes*, *Limnias*, *Megalotrocha*, *Brachionus*, and *Rotifer vulgaris*. The different ponds and ditches round Bristol where these were most likely to be found were added, and many useful hints given about their capture.

Mr. E. Tawney then read "Notes on Trias Dykes," while the "Notes on the Radstock Lias," and Mr. Stoddart's on "The Geological Distribution of Mosses in the Bristol District," were taken as read. All appear above.

December 3rd, 1874. On the eighth evening Meeting Mr. W. W. Stoddart, F.G.S., read the second part of his paper on the "Geology of the Bristol Coal-field.—Silurian and Devonian." It was illustrated by numerous large diagrams, and by a collection of fossils from the beds referred to.

BOTANICAL SECTION.

January 15th, 1874. The Annual Meeting. After the usual routine business, Mr. Leipner was re-elected President, with thanks for his past services. Mr. Yabbicom having stated his desire to be relieved from the office of Honorary Secretary, which he had held from the formation of the Society, Mr. Hudd proposed, and Mr. Halsall seconded, the resolution, "That while this section regrets M. Yabbicom's decision not again to accept the office of Honorary Secretary, they wish to express their thanks for his services during the past ten years." The same was carried unanimously. It was proposed by Mr. Yabbicom and seconded by Mr. Hudd, "That Mr. C. B. Dunn be elected Honorary Secretary for the ensuing year."

January 21st, 1874. The minutes of the last Ordinary Meeting having been read and passed, the evening was spent in examining the specimens contained in the Society's herbarium.

February 28th, 1874. This being the first excursion of the season, the members met at three p.m. at the Suspension Bridge, and, proceeding through Leigh Woods, walked over the high ground to Failand. The stream was flowing gently over a bright green bed of *Nasturtium officinale;* the adjacent banks were lined with masses of *Jungermannia* beautifully in fruit; *Polytrichum, Hypnum, Bryum, Bartramia, Fontanalis* and other mosses being collected in the neighbourhood.

March 28th, 1874. The members met the President at Durdham Down, and passing through Mr. Adam's farm, Mr. Leipner drew attention to the moss-covered walls—*Tortula* *ruralis*, *T. muralis*, *Bryum cæspitosum*, &c. In crossing Combe Dingle, a *Populus niger* was noticed, having large clusters of *Viscum allum* growing on the branches. In the Arbutus walk we gathered *Vinca minor*, Mr. Halsall informing us that no finer specimens of *Arbutus Unedo* were to be found in Killarney itself, the tree being a native of Ireland.

April 25th, 1874. The Hon. Secretary met the members at three p.m., at the Clifton Bridge Station, and took the train to Portbury, where a couple of hours were very pleasantly spent in the woods, which were literally a carpet of flowers. The *Prunus cerasus* was in blossom; several specimens of *Paris quadrifolia* with five leaves were gathered; also the white variety of *Hyacinthus nonscriptus*.

May 30th, 1874. The President met the members at the Clifton Bridge Station, and, proceeding by train to Portishead, the party carefully botanised from the Station to the spring on the far end of the beach. *Sherardia arvensis* very plentiful; *Euonymus Europæus* in flower. In the wood certain trees had quite a red tint, found to be *Acer campestre*, covered with samara, the tips being tinted. *Scrophularia aquatica* and *Althæa officinalis* were also gathered.

June 25th, 1874. At 12 p.m. the members met at the Bristol and Exeter Platform, and took return tickets to Cheddar. Passing through the village the ancient cross attracted attention, the stone canopy having thick clusters of *Polypodium vulgare* and *Asplenium trichomanes* adorning this relic of a former age. The Rev. Richard A. Court Beadon very courteously explained the various portions of the fine old church recently restored. Wandering through the lanes and over the fields, the party gained the summit of the cliffs. Glastonbury Tor was just visible through the coming storm, and to seaward there was a most extensive view in a sheen of sunlight. After the storm had passed we gathered *Thalictrum minus* and *Polypodium calcareum*; and descending into the gorge we found *Meconopsis cambrica*; passing through the ravine we saw, high up on the sides, beautiful tufts of *Dianthus cœsius*, covered with delicate pink flowers; finishing a most enjoyable ramble by refreshment at the Bath Arms.

October 15th, 1874. The first evening meeting of the next Session was held at the Museum and Library. The Honorary Secretary read the minutes for the past meeting, &c. They were duly signed and passed, and the evening was occupied in examining the specimens collected during the summer excursions.

November 19th, 1874. The minutes of the last meeting having been read, Dr. Burder exhibited a flourishing specimen of *Eucalyptus globulus*, which he had raised from seed, the Dr. observing that it was a tree that had of late attracted considerable attention in reference to its health-giving properties, that the great amount of moisture taken up by the roots in their rapid growth might be one reason of its capabilities for draining a marshy district, also that the tree gave out a refreshing balsamic odour.

Mr. Leipner, thanking Dr. Burder for his kindness in bringing the subject before the meeting, said that the plant belonged to the natural order *Myrtaceæ*, and hence we might expect to find, from the pellucid dottings of the leaves, the presence of a fragrant aromatic volatile oil, which gives the principal quality to this order, *e.g.*, the grateful perfume of the Guava fruit, the balsamic odour of many Eastern fruits. Mr. Leipner reminded the audience that the genus *Eucalyptus* contained the largest trees in the world, the *E. amygdalima* (an account of which may be seen in the *Proceedings of the Bristol Naturalist's Society*, December 7th, 1871) being 480 feet in height, the first branch being 200 feet from the ground.

Several members spoke on the subject, in reference to the peculiarity of Australian forests—namely, in their leaves presenting their margin, and not either surface, towards the stem. In the Acacia this is in consequence of the vertical dilation of the foliaceous foot stalk; while in the gum trees (Eucalyptus), where, though general, it is by no means universal, it is produced by the twisting of the foot stalk of the leaf. The foliage is scanty, of a peculiar pale green or blue tint, hence the woods appear light and shadowless. The bark of the Eucalypti falls annually, or hangs loose in long shreds, giving to the forest a weird and desolate appearance.

Mr. C. B. Dunn being called upon to give the subject on the notice circular, "Morphology," he proved by specimens and diagrams that a flower, from the bract to the ovule, is composed of metamorphosed leaves.

December 17th, 1874. The Honorary Secretary, in the unavoidable absence of the President, brought forward the subject of a local museum being formed during the meeting of the British Association in Bristol, next year, whereupon Mr. Yabbicom proposed, and Mr. Giles seconded, the following resolution:—"That this Section approves of the proposal to establish a local museum during the visit of the British Association, and promises its assistance."

The Chairman having called upon Mr. Yabbicom for the subject of the evening, "O'er the Down in December," Mr. Yabbicom said that little could be expected, considering that the Downs were several inches deep in snow. Producing a small botanical case, he proceeded to exhibit its contents, and explained the pecularities of each specimen. A few Phaneragans, and a very fair collection of Cryptogams, including Fungi, Mosses, and Lichens, made up the list.

ENTOMOLOGICAL SECTION.

Jan. 14th, 1874. At this Meeting a paper was read by Mr. Grigg on the life history of *Epunda nigra.* Eggs of this species was obtained from a female captured on ivy bloom in October, 1871, no less than eight hundred being deposited. The eggs are of a light straw color, of a flattened rounded form, finely fluted from the centre of the top to the base. The eggs become blackened a few days before hatching, the young larva appearing towards the end of February, and were full fed in June. When fully grown the larva are about 1½ inch in length. They were found to feed freely on chickweed, spinach, and dock. Before turning to chrysalis a brittle earthen cocoon is formed just under the surface of the ground. The first moth appeared on October 27th, 1872. Mr. Griggs's paper was illustrated by drawings of several varieties of the larva.

Excursions were taken during the summer to Brean Down, near Weston-super-Mare, to Brockley, and to Nailsea Marsh.

At the December Meeting Mr. Grigg read some notes "On the occurrence of *Platypteryx sicula,*" a species peculiar to Bristol, as far as Great Britain is concerned. Some forty years ago a single specimen was taken by Mr. Metford, and this remained for about twenty-five years as the only British example of the species. Fifteen years ago several specimens occurred, and again the species disappeared until 1874, when five examples were taken. The species has been constantly looked for, and its fitful appearance is very singular. In searching for this species

Mr. Grigg nearly lost his life through falling down a disused shaft or well, some twenty feet or more in depth. Mr. Grigg mentioned his having come across some four or five of these open shafts in Leigh Woods, in depth from fifteen or twenty feet to one hundred feet or more.

Among the British specimens exhibited at the different meetings of the Section may be mentioned *A. Niobe*, *A. Lathonia*, *Nola albulalis*, *Leucania albipunta*, *Agrotera nemoralis*, *Nascia cilialis*, *Halonota grandoeva*, and *Pterophorus rhododactylus* ; also a large number of European and exotic species.

GEOLOGICAL SECTION.

February 11th, 1874. The first evening Meeting of this Section was the Annual Meeting. The President and Hon. Secretary were re-elected; the accounts were passed, and from the balance one guinea was presented to the Library Fund of the parent Society. There were no other evening Meetings this year, but the following out-door meetings during the summer took place.

April 17th, 1874. The first excursion of the Section was to Aust Cliff. The party consisted of ten. From the New Passage Station there is a walk of about 40 minutes along the Severn embankment before the Aust Cliff is reached. This Cliff is a prominent object for some miles down the river: it is the section or river exposure of a large outlier of New Red Rhætic and Lias standing out boldly in the alluvial plain. The shores were hunted for the well-known Rhætic and White Lias fossils, but no fresh material was down, and the few blocks of Bone-bed seen had already been picked over a few days previously. Though not many fossils were found the Bone-bed was seen *in situ*: the faults and celestine veins were also examined; there is always something interesting in this section to arrest attention; and among other things which engaged attention was the apparently sudden change from unfossiliferous green marls to the wonderful Bone bed layer which lies next in succession; again the alternation of green and red marls, the fitful oxidation of the iron which causes these colours, will still give ground for study. Also the segregation of large gypsum masses, at one time in layers, at other times in strings, in all directions through the beds, was noticed, but no very satisfactory explanation arrived at.

May 26th, Whit Tuesday. At the invitation of Professor Buckman this holiday was taken advantage of for a whole day excursion to Sherborne and its neighbourhood. A party of twenty members, including the Secretary of the Bath Nat. Hist. Field Club, took train to Yeovil, where they were met by Prof. Buckman, who led them to some sections of the Inferior Oolite Sands in deep lanes, and thence to his house at Bradford Abbas. The quarry close by was first visited, where fossils are exceedingly abundant. This is where the Professor has obtained so many things in his fine collection. Many fossils are said to be found here in the same bed which in Gloucestershire are usually separated by a considerable thickness of strata. The richness of fossil remains was certainly noticeable compared to localities round Bristol, not excepting even Dundry exposures. The deposits may be probably much condensed, and therefore fossils more crowded together. Lunch was most hospitably offered by the Professor, and his collection of fossils opened for inspection. Leaving then the hospitable house, the geologists followed in the steps of the Professor by his model farm to the Half-way-house, near Sherborne. More fossils were found at this classical locality, and when good bags had been made, the way was pursued along the highway towards Sherborne. An interesting fault was noticed and further sections of the Inferior Oolite Sands. It is thought that these Sands may be probably not quite the same age as the Upper Lias Sands in Gloucestershire. Prof. Buckman said that he had obtained from the Sherborne district all the Gasteropoda which were described in the last number of the *Proceedings of the Bristol Naturalists' Society*. On arriving at Sherborne the Abbey was inspected by some of the party. The next move was to the Hotel, where the Professor invited his guests to a most generous dinner. Pleasant reminiscences of the last time when the Professor accompanied our Society were recalled, and the unfortunate oversight by which a fine collection of grasses which we then made were lost, together with other mishaps, such as losing the steamer, were explained to those who had not been present that day. Finally the Professor's health having been cordially drunk, the party made for the station, and heartily thanking their guide for a most happy and instructive day, and for his many hospitalities, they returned by train home.

June 26th, 1874. The day was, unfortunately, very wet, and only six members joined the excursion. Train was taken to Wookey, the object of exploration being Wookey Hole. This fine cavern, which has been so often described, is in the Magnesian Conglomerate. The stream now issues much below the entrance to the cavern. Close by here is the Hyœna Den, so minutely described by Professor Boyd Dawkins (see "Cave-hunting," 1874).

September 23rd, 1874. The fourth field day was to the Radstock district. Twelve members attended. They were met at Radstock Station by Mr. Sherring, who conducted them first to some Lias quarries at Huish, where both L. and M. Lias is seen. Numerous fossils were obtained, particularly *Pholadomya ambigua*, and Brachiopoda. The way was retraced to Radstock, and there a round was taken by Clan Down, Mungar, Phyllis' Hill, Ham Lane, and Paulton. Mr. Sherring had thoughtfully brought his wagonette and a pony chaise down, and this most materially saved time in getting over the ground. The quarries visited contain many fossils of interest, but as they are all of them noticed in one of the essays above, it is unnecessary to repeat details here. Mr. Sherring finally guided the party to his house, where he had prepared a most hospitable dinner. This terminated a very pleasant day, but no means the first, as was observed in returning him thanks, that the Society owe to his kind solicitude.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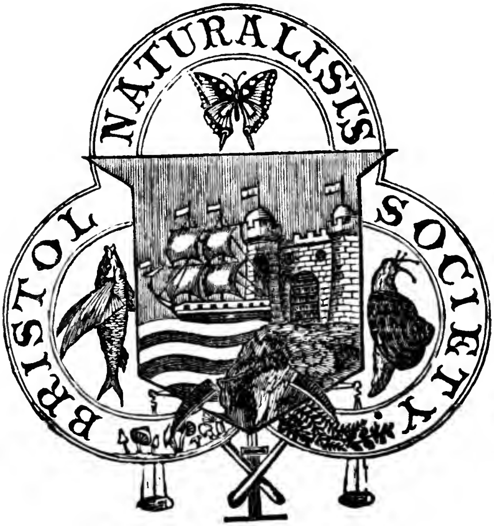

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TABLE OF CONTENTS.

NEW SERIES, VOL. I. PART III.

REPORTS OF MEETINGS AND EXCURSIONS.

[Authors alone are responsible for the various statements and opinions in their respective papers.]

The Society is again indebted to Mr. Stoddart for presenting the cuts and folding plate which illustrate his paper. Also to Mr. Walter Derham, for the two excellent plates of Fossil Encrinites, and to the Editor for the Index to Vol. I.

Geology of the Bristol Coal-field.

PART 3.—CARBONIFEROUS.

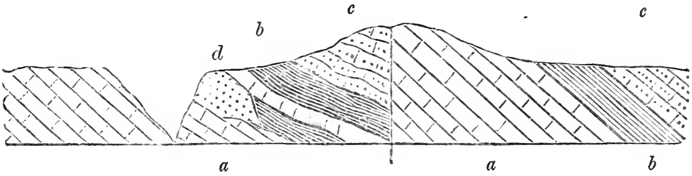
Read at the General Meeting, March 4th, 1875.

WE now arrive at the principal and most important part of our subject, viz., the coal measures and their adjacent rocks. The various beds of the Carboniferous series may be more extensively displayed in other parts of Great Britain, but in no place are they so well shewn collectively, or so well adapted for study as in our own immediate neighbourhood. Each division is very rich in all the characteristic fossils, in examples of faults, anticlinals, upheavals, denudation, and other types illustrative of Physical geology. Crystallography and Mineralogy are no less fully developed in those crystals and minerals peculiar to the Carboniferous Limestone.

It is principally to these rocks that we owe our Clifton, Cheddar, Mendip, and other exquisite bits of scenery, for which Somersetshire and Devonshire are so celebrated.

We find the Carboniferous follow the Devonian Sandstone gradually and conformably, commencing as argillaceous strata, then changing into pure massive limestone, and ending in many hundred feet of grits and sandy beds. In several localities to be subsequently described, we find these limestone beds forming immense hollows many miles in diameter that were afterwards filled up by stores of coal, which now constitute directly, or indirectly, so great a source of our national prosperity. Here and there we find some exercise of terrestial force has disjointed and displaced immense thicknesses of rocks, dislocating and twisting them into the most fantastic shapes. Perhaps the most remarkable of these faults, and one that is most fully displayed, is that on the north bank of the Avon. Here is a displacement, vertically, of more than eight hundred feet, dividing the Clifton series into two parts, sinking the one and upheaving the other, till we see apparently, as we walk down the river side, two sections of the same beds. This is explained roughly by fig. 14.

Fig. 14.—*Clifton Fault.*



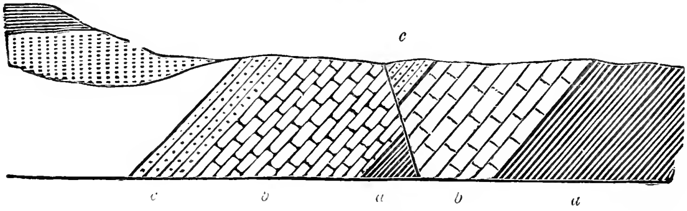
a Massive Limestone.—*b* Upper Limestone Shales.—*c* Millstone Grit.—*d* Magnesian Conglomerate.

The destruction caused by this tremendous convulsion was still more intensified by concluding with an awful lateral pressure which crushed the broken rocks into contortions, mixing them with later formations in the utmost confusion.

With broken masses of limestone we see millstone grit, marls, magnesian conglomerate, and beds of coal mingled together without the slightest reference to order of deposition. Any one walking past this spot will see an unrivalled section more than three hundred feet thick and a quarter of a mile long.

Another well-marked fault is met with in the Wick Rocks, and interfering with the beds of coal, as seen in fig. 15.

FIG. 15.—*Wick Fault.*

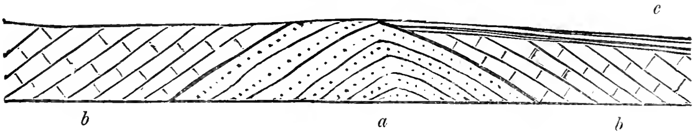


a Devonian.—*b* Carboniferous Limestone.—*c* Millstone Grit.—*d* Lower Coal Measures.—*e* Trias.—*f* Lias.

Other examples are to be met with, but not so well displayed. It is probable that these faults were caused by internal forces beneath the crust of the earth about the commencement of the Triassic period. At any rate, dreadful as were the results to the then existing surface, yet they were the means of bringing within our reach the rich stores of coal. Many of the coal seams lay so deeply that, had not this upheaval of the country taken place, we could not possibly have reached them.

Another variety of the disturbance of strata occurs very frequently. A large mass of older rocks are forced up to the surface through those of later age. We have already noticed some as of Silurian at Purton (*page* 263), and at Tortworth (*page* 267) of Devonian as at Brockley Combe (*page* 268), and of Basalt at Downhead (*page* 270). As seen in fig. 16 representing the rocks through which the Wickwar tunnel passes,

FIG. 16.—*Wickwar Anticlinal*



a Devonian.—*b* Carboniferous Limestone.—*c* Lias.

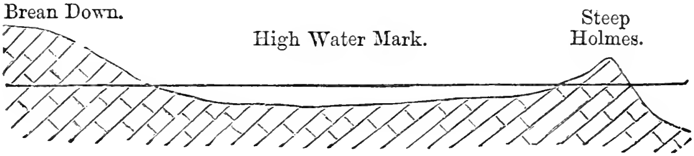
the Devonian sandstone has been forced through a large thickness of limestone, supporting the latter on both sides like the roof of a house, and forming what the geologists call an anticlinal. After this period this peculiar form of upheaval seems to have ceased. All the later faults, though numerous, are mere cracks as it were in the strata, interrupting the continuation of strata only.

The Carboniferous system is divided into two grand divisions—the Limestone rock proper, and the Coal measures. The first and oldest of these is sub-divided into three groups, viz.—

The lower shales about 500 feet in thickness.
The mountain limestone about 2000 do.
The upper shales about 400 do.

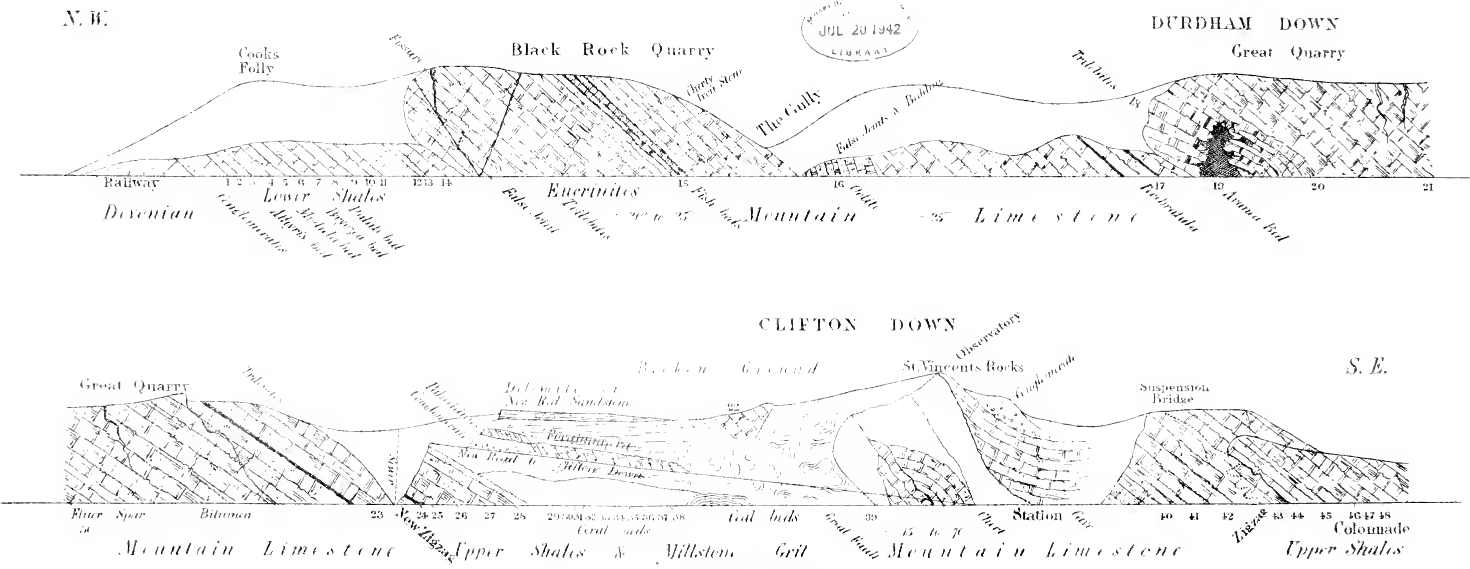
In comparatively recent times, the limestone beds became worn down by the action of air and water. A familiar instance of the effects of the long continued wave action must be familiar to all who visit Weston-super-mare. When standing on the summit of Brean Down and looking towards the Steep Holmes at dead low water, the ripples on the water distinctly mark the edges of the limestone strata that are only just covered by the sea. These prove that the island rock was once connected with the shore, but now separated by denudation. Their position is explained by fig. 17.

Fig. 17.—*Section between Weston and Steep Holmes.*



The magnificent and continuous section of the first division of the Carboniferous system is so perfectly exposed on the Gloucestershire side of the Avon, that we will take it as a fine summary of the whole series as observed in the counties of Gloucestershire and Somersetshire. The junction of the Devonian into the Carboniferous strata is complete, and the gradual passage into the lower shales

DIAGRAM OF THE AVON SECTION.



with the characteristic beds of fossils can be studied with so much facility and advantage, that we do not hesitate to take the Clifton section as a typical example, following as a guide the accompanying sketch.

The Section commences with Devonian strata 360 feet thick, passing gradually through 500 feet of Lower Limestone shales, then through 2000 feet of Mountain Limestone, and finishing off with 400 feet of Upper Limestone shales and grits, and 1000 feet of Millstone grit.

Every bed may be studied without any dangerous climbing, and with the greatest facility, and in order to facilitate the labours of those who may wish to pay a visit, and who may not be conversant with the locality, the following description, it is hoped, will be amply sufficient to supply the place of a guide. The number of feet indicate the vertical distance from the commencement of the section below Cook's Folly, taking the railway as the datum line, while the numbers of the several beds correspond with those on the diagram. As may easily be imagined, the catalogue of fossiliferous beds is so immensely long that only a few of the most interesting have been taken.

The Devonian beds that commence the first 360 feet of the section, are generally sandstone, containing Mica, but devoid of Carbonate of Lime and Fossils. At the distance of 327 feet are three remarkable beds of quartzose conglomerate 6 feet thick, divided by thin partings of purple and green marls. The pebbles are pieces of quartz which have had their angles completely worn away from long continued water action, and are probably the bed of an ancient river near the sea.

Thirty-three feet above the conglomerates is the first bed that contain any appreciable quantity of lime, and may therefore be considered as the commencement of the true Carboniferous section. The junction of the Old Red and Carboniferous is so gradual that it is impossible to say where one ends and the other begins, but the junction beds may be included between the conglomerates and the bed now mentioned.

LOWER CARBONIFEROUS SHALES.

The figures within [ ] denote the number of feet from the commencement of Section.

1.—[360].—First bed with carbonate of lime in any quantity, and one foot thick.

2.—[385].—*Athyris Roysii* bed of very aluminous limestone 2 feet in thickness. Every part of the bed is crowded with fossils. The most characteristic are:—*Athyris Roysii* (Dav.,) *Spirifera rhomboidea* (Phill.,) *Retzia radialis* (Phill.)

[400].—Hard dark limestone 3 inches thick, resting on 12 inches of yellow marl. The stone is full of minute shells, probably the young of *Naticopsis* and *Rissoa* and *Cytheridæ.*

3.—[408].—*Sanguinolites shales.* Greenish arenaceous shales, very fissile and with abundant and good casts of *Sanguinolites augustata* (Phill.) and *S. complanata* (Phill). A good spot for collecting them is a few yards in the wood.

4.—[413].—*Modiola shales.* This is probably the most important bed of the Lower shales, for many of the fossils are identical with those of the Marwood, Coomhola, Moyola, and the Scotch Coal Measures, so that they go far to support the idea of some of the Upper Devonian belonging rather to the Carboniferous period. Another fact is that the whole of the beds are full of grass-like weeds similar to those of shallow sea shores, or rather to land at a low altitude which is periodically subject to the influence of high tides. Mixed with these plants are immense masses of the cast off valves of entomostraca.

The late Professor Jukes said, "If the Coomhola grits be classed with the Carboniferous series, the so-called Upper Devonian of Devonshire must be classed with the Marwood group as Carboniferous; and if classed with the Devonian, they must be set aside as a distinct sub-group."

The following is a comparative table of these "Modiola" fossils, which appear to render the above mentioned idea conclusive.

	Clifton	Marwood	Coomhola.	Moyola.	Scotch Coal Measures.
Leperditia Okeni	x	—	—	x	x
—— —— var. subrectus...	x	—	—	x	x
Filicites dichotoma	x	—	x	—	—
Knorria dichotoma	x	—	x	—	x
Platycrinus	x	—	x	—	—
Poteriocrinus	x	—	x	—	—
Rhodocrinus	x	—	x	—	—
Serpula omphalodes	x	x	—	x	x
Lingula parallela	x	—	—	x	x
Spirifera disjuncta	—	x	x	x	—
—— bisulcata	x	x	x	x	—
Streptorhynchus crinisria..	x	x	x	x	—
Rhynchonella pleurodon ...	x	x	x	x	—
Cucullœa trapezium	x	x	—	—	—
—— Hardingii	x	x	—	—	—
Modiola Macadami	x	x	x	x	—
Avicula Damnoniensis ...	x	x	x	x	x ?
Naticopsis plicistria	x	—	—	x	—
Amblypterus Portlocki ...	x	—	—	x	x
Orthoceras gragarium ...	x	—	x	x	—
Chonetes Hardrensis ...	x	x	—	—	—
Discina nitida	x	x	—	—	—
Athyris Royssii...	x	—	—	—	—
Terebratula hastata	x	—	—	—	—

5.—[433].—*Fenestella bed.* This is light coloured limestone about 1 foot thick, containing plenty of good specimens of *Fenestella flabellata* and other Bryozoa.

6.—[448].—*Bryozoa bed.* This very remarkable deposit is 8 feet thick, of dark red siliceous rock mixed with crystalline limestone. It is one mass of minute casts of fossils in a compound of silica and ferric oxide. They being insoluble in tolerably strong Hydrochloric acid may be easily separated from the lime. A very favorite method of preparing specimens is to suspend a piece of the rock in a beaker of acid till a portion has been dissolved, then removed and dried. The fossils then appear all over the surface, standing out in the most beautiful manner. On gently washing the sediment in the beaker plenty of loose fossils may be obtained ready for the microscope. To give an idea of the immense number of organisms present in the rock, more than one million and a half have been obtained from only one pound of stone. A description of the Bryozoa bed will be found in the Ann. Nat. Hist., 1861, p. 486. The chief bulk of the fossils are joints of the arms of Encrinites. All of them are very minute, the larger Entrochi from the stems having been washed away, just as in a heap of pebbles, the larger ones roll to the bottom. So here we find the outside of the bank on the opposite side of the river. There we find the particles much larger, mixed with good sized *Productæ*, and sometimes the tooth of a *Psammodus* or *Cladodus.*

The following are fossils that are always present, and may be obtained at any time :—

Ceriopora rhombifera (Goldf.); *Platycrinus lævis* (Mill.); *Poteriocrinus isacobus?* (Aust.); *Leperditia Okeni* (Munst.); *Cypridina ovalis* (Stod.); *Cytherella lunata* (Stod.); *Naticopsis plicistria* (McCoy.), (Young); *Productus* (Sp ?); *Spirorbis triangulatus* (Stod.); *Psammodus porosus* (Ag.): *Cladodus conicus* (Ag.)

7.—[453].—*Palate bed.* This is a breccia 5 feet above the Bryozoa bed, full of fish teeth and coprolites with shells, &c. Very good specimens may be easily obtained, especially from weathered portions. When seen in a freshly made section of the rock, this palate bed has a greyish brown colour, but on exposure to the air it soon changes into a dark reddish brown from oxidation of the iron. The bed is three or four inches in thickness, and lies on eighteen inches of greyish marl. The principal fossils are :—

Discina nitida (Lam.); *Lingula mytiloides* (Dav.); *Naticopsis plicistria* (McCoy.); *Conularia quadrisulcata* (Mill.); *Loxonema rugifera* (Phill.); *Cladodus conicus* (Ag.); *Chomatodus linearis* (Ag.); *Helodus levissimus* (Ag.); *Psammodus porosus* (Ag.); *rugosus* (Ag.)

8.—[495].—*Camarophoria bed.*—This is a 6 inch dark coloured bed of limestone containing in great numbers—

Camarophoria globulina (King.); *Athyris Royssii* (Dav.), *lamellosa* (Dav.); *Retzia radialis* (Phill.); *Naticopsis plicistria* (McCoy.); *Spirifera duplicicostata* (Dav.)

9.—[506.]—*Buchiana bed* is one of grey limestone from 12 to 20 inches in thickness, and is one mass of mollusca cemented togethe with carbonate of lime. Very perfect specimens with the shell may be easily obtained in great numbers and perfection. The following fossils are the most common in a very long list obtainable in this spot.

Chonetes Buchiana (Dav.), *sordida* (Sow.), var *perlata, papilionacea* (Kon.); *Orthis resupinata* (Mart.); *Streptorhyncus crenistria* (Dav.) var. *arachnoidea* (Dalm.): *Sanguinolites transversa* (Portl.)

10.—[520].—*Pleurodon bed.*—This is marked out on account of containing Rhynchonella pleurodon, which is not found in the Clifton rocks so abundantly as in the Derbyshire and many other limestones. The two chief fossils are:—*Rhynchonella pleurodon* (Fisch.); *Cladodus conicus* (Ag.)

11.—[535].—*Fenestella bed,* so called from the remarkable abundance of bryozoa that are found in it. Excellent specimens may be collected on the railway bank, where the little branched polypidoms attract the eye, standing out in relief on the weathered slabs of limestone. From this bed are also collected the heads of Encrinites in a good state of preservation.

Ptylopora pluma (McCoy.), *flustraformis* (Phill.); *Fenestella flabellata* (Lonsd.), *irregularis* (Phill), *polyporata* (Portl), *membranacea* (Lonsd.); *Retepora prisca* (Lonsd.); *Ceriopora interporosa* (Goldf.), *rhombifera* (Gold,); *Streptorhyncus crenistria* (Phill.); *Orthis resupinata* (Mart.); *Encrinites* (various.)

12.—[639].—*Trilobite bed.*—This limestone is very rich in the Phillipsia, of which only the pygidia will probably be found. The pretty little *Chonetes perlata* or as it is sometimes called *C. Hardrensis* is very plentiful. A good spot for this bed is on the top of the hill where it crops up at the back of Avonhurst house, Sneyd Park. Although varieties of the same trilobite, yet the difference as pointed out in Portlock's report on Tyrone, &c., are so marked that the names are retained as a guide to the visitor.

Phillipsia pustulata (Schlot.), var. *Brongniarti* (Fisch.) var. *seminifera* (Phill.); *Chonetes sordida* (Sow.), var. *perlata* (Phill.).

13.—[639].—*Oracanthus bed.*—This is another of our well marked

Clifton beds of fossils. It is about a foot thick, and is extremely rich in Brachiopoda and the sculptured defensive spines of *Oracanthus*. The best opportunity for examining it was a short time ago when an excavation was being made for a house in Sneyd Park, on the road to Stoke Bishop. The limestone weathers easily, and being rather argillaceous the various specimens are more easily and perfectly separated from the matrix than they generally are. The collector should look out for *Rhynchonella acuminata* and *Spirifera Mosquensis*, which are great rarities.

Oracanthus pustulatus (Ag.), *Millerii*, (Ag.), *minor* (Ag.), *Terebratula hastata* (Sow.), var. *ficus*, (McCoy.), var. *sacculus* (Mont.), v. *vesicularis* (DeKon.); *Rhynchonella acuminata* (Sow.); *Spirifera Mosquensis* (Dav.) *glabra* (Dav.) *duplicicostata* (Dav.) *Streptorhyncus crenistria* (Dav.), v. *arachnoidea* (Dalm.); *Strophomena analoga* (Phill.), *Orthis resupinata* (Mart.); *Cypricardia rhombea* (Mus. Pr. G.), *parallela* (Phill.); *Capulus vetustus* (Montf.); *Euomphalus Dionysii* (Goldf.)

14.—[668].—*Spirifer bed.*—This bed is instantly recognised by the abundance of fine specimens of *Spirifera striata* that occur. It is several feet thick and very dark in colour, and is the last illustrative bed of the true Lower Carboniferous Shales that we shall notice. It must not however be supposed that the intervening strata are unfossiliferous. On the contrary the whole of the set of beds is extremely rich, especially in Brachiopoda, so much so that it is extremely difficult to select any special ones. The one now under consideration may be recognised as the commencement of the Black Rock Quarry, and contains chiefly—

Psammodus porosus (Ag.); *Spirifera striata* (Dav.), var. *attenuata*, *cuspidata* (Mart.); *Producta punctata* (Mart.), *pustulosa* (Phill.); *Athyris Royssii* (Dav.).

MOUNTAIN LIMESTONE.

It is difficult and arbitrary to draw any line of demarcation in the Clifton section, so gradually does one part pass into the other. We have, however, for convenience of description, commenced the massive mountain limestone with what is locally known as the

Black Rock Quarry. It is so named from nearly all the beds being very dark in colour, from the presence of bitumen, which sometimes is so plentiful as to give an unpleasant odour to the limestone, especially when rubbed, and sometimes is found as a liquid in small cavities. The quarry is an extensive one, being 770 feet in length, and nearly 300 feet in height. The dip of the beds varies from 20° to 30° to the S.S.E. They are famous, both in this country and elsewhere, for the remains of gigantic fishes that once swarmed in the water of the old carboniferous ocean. Our Museum contains a fine collection of typical specimens, the originals of many of the figures in the large work of Agassiz on fossil fishes. The strata in this quarry are extremely regular and uniform. At the top of the eastern extremity is a singular deposit of cherty ironstone, which appears to have been the result of decomposition. It is full of vacuoles, as if caused by the escape of gases, but no trace of fossils can be seen.

[899].—*Encrinite beds.*—These attain a thickness of 112 feet, and constitute a very large part of the quarry. The stone is one complete mass of the stems, arms and heads of these exquisitely beautiful echinoderms, the sea lilies. The stone, when polished shews the forms in the most perfect manner, and are very favourite specimens and in great request for ornamental work. In the centre of these Encrinital Beds is one in which the largest specimens of Trilobites have been found. It is singular that in this one layer there should have been so many, when they are absent in the others. Nearly all the species of Encrinites yet found have been noticed in this spot.

Agathocrinus planus (Mill.); *Dichocrinus radiatus* (Aust.); *Poteriocrinus conicus* (Phill.), *crassus* (Mill.), *isacobus* (Aust.), *plicatus* (Aust.), *pentangularis* (Mill.), *tenuis* (Mill.), *rostratus* (Aust.), *Rhodocrinus costatus* (Aust.); *granulatus* (Aust.), *verus* (Mill.); *Platycrinus granulatus* (Mill.), *levis* (Mill.), *rugosus* (Mill.), *striatus* (Mill.), *trigintidactylus* (Aust.); *Actinocrinus triacontadactylus* (Aust.)

15.—[961].—*Fish beds.*—At this spot are three beds, so remarkably uniform in thickness and parallelism as to be strikingly noticeable to anyone passing, and therefore, form a capital guide to this wonderful deposit of Ichthyodorulites. The defensive spines of *Ctenacanthus* sometimes attain a length of 20 inches or two feet. These formidal weapons formed part of the dorsal fins of immense sharks, with grinding teeth like those found near Port Jackson, in Australia. In consequence of these fishes being cartilaginous in their structure, only these spines and the teeth have been preserved, the soft portions having probably disappeared.

The following is a list of fossil contents :—

Cladodus conicus (Ag.), *Milleri* (Ag,), *mirabilis* (Ag.); *Deltoptychius acutus* (Ag.); *Tomodus convexus* (Ag.); *Chomatodus cinctus* (Ag.), *linearis* (Ag); *Cochliodus contortus* (Ag.); *Ctenacanthus brevis* (Ag.), *major* (Ag.), *tenuistriatus* (Ag); *Helodus gibberulus* (Ag.), *lævissimus* (Ag), *subteres* (Ag.), *turgidus* (Ag.); *Onchus hamatus* (Ag.), *sulcatus* (Ag.); *Oracanthus Milleri* (Ag.), *minor* (Ag.), *pustulosus* (Ag.); *Orodus cinctus* (Ag.), *ramosus* (Ag.); *Psammodus porosus* (Ag.), *rugosus* (Ag.).

A long series of interesting beds follow to the end of the quarry, and terminate in a deep ravine leading to the summit of Durdham Down, near what is called the Sea Wall, from which a magnificent panorama is beheld, comprising the fine anchorage ground of Kingroad, backed up by the Welsh Hills.

It is on the side of this ravine that a botanical rarity may be gathered, *Grimmia orbicularis*, a round fruited moss.

On passing the opening of this ravine, we come to a singular series of beds, 167 feet in thickness, of Oolitic limestone, so full of false joints as to give the beds the appearance of having a vertical position, although they really dip 30°. The oolitic structure is extremely fine, each granule having in its centre a minute speck of sand, A great number of microscopical examinations have been made, but have hitherto failed in finding any organic nucleus. On passing these, we come to more regular beds, containing fossils, but only stay to notice one (16).—[1433], having a brown colour, situated 44 feet above the oolitic strata just mentioned, and is entirely composed of myriads of the valves of *Terebratula hastata*, and 6 inches thick.

17.—[1526].—*Aranea bed,* or grey limestone, full of the *Lithostrotion aranea.* The delicate web-like tracery of the septa are shewn very distinctly. It contains a small branched coral whose name has not been definitely determined.

Lithostrotion aranea (Edwds.), *irregulare* (Edwds.), *junceum* (Edwds.); *Producta punctata* (Mart.).

We now come to the Great Quarry, another extensive section, 1185 feet long, and the same height as the Black Rock. Here the limestone is generally lighter in colour, and, in some places, very bituminous. Between the limestone beds we frequently find cubic crystals of the Fluor Spar. At the western end is a very singular fracture of the beds by subsidence. During the progress of deposition, a portion has evidently been washed away, letting the superincumbent roof of five or six beds fall in; this was evidently not a recent occurrence, because the subsequent thickness of some 200 feet was afterwards regular, and shows no sign of disturbance.

18.—[1539].—*Longispinosus bed* occurs about 15 feet before the commencement of the Great Quarry. It is a smooth, thin, and argillaceous bed completely covered with Trilobites, a Productus with very long spines, Bryozoa, and other organisms.

Producta longispinosa (Sow.); *Phillipsia pustulata* (Schloth.); *Ceriopora rhombifera* (Goldf.) *Lithostrotion junceum* (Edw.); *Entomostraca; Foraminifera.*

19.—[1552].—*Euomphalus bed* is one of the first beds of solid limestone with which we meet in the quarry. It is a rather light coloured limestone, and very fossiliferous, and contains some good specimens of Euomphalus and Producta.

Euomphalus nodosus (Sow.), *calyx* (Phill.); *Producta Martini* (Sow.), *Cora* (D'Orb.); *Rhynchonella acuminata* (Sow.).

20.—[1617].—*Portlocki bed* is full of the beautiful astreiform corals in brown limestone, a section cut from any part is an equally good example.

Lithostrotion Portlocki (Edwds.); *Cyathophyllum regium* (Phill.), *turbinatum* (Sow.); *Michelinia tenuisepta* (Goldf.).

21.—[1620].—*Cyrtina bed* contains good specimens of *Cyrtina septosa* (Dav.); *Spirifera lineata* (Mart.).

[1849].—Here we come to the end of the quarry, and arrive at the new zigzag path from Clifton Down. At the top of this, on the Durdham Down side, may be taken good examples of *Phillipsia*, although not plentifully distributed. On the edge of Clifton Down, at the top of the road, is an interesting three inch black bed, which is only here exposed, which we name the

22.—*Bellerophon bed.* This limestone is noticeable for allowing the fossils to come away in a perfect state by a blow of the hammer, so that no occasion exists for carrying home a large piece of the matrix, as is usually unavoidable.

We now arrive at one of the great points of interest in the Clifton rocks, viz., the remains of a former coral reef. Throughout the next 1290 feet the rocks are entirely filled with the most lovely forms of Zoanthidœ, which, from their large size, must have thriven in the greatest luxuriance in the warm waters of the ancient carboniferous sea. Here may be seen tons of Cyathophyllidœ, three inches in diameter, and of proportionate length with the tiny *Alveolites* and *Syringopcra*, surrounded with the washings of the waves and the entomostraca that usually inhabit such localities. Indeed, here may be exhibited the natural history found at the bottom of a tropical sea.

23.—[1859].—*Aulophyılum bed*, is a reddish brown limestone with

Aulophyllum fungites (Edwds.); *Clisiophyllum coniseptum* (Keys.) *Lithostrotion concinnum* (Edwds.); *Cyathophyllum regium* (Phill.).

24.—[1892.]—*Ellipsolithes bed* is a thin bed, and is the chief locality in which we can get.

Ellipsolithes compressus (McCoy.); *Euomphalus tuberculatus* (Thor.).

25.—[1897.]—*Vesicularis bed* is a good one for this variety of *Terebratula hastata*, of which it is probably the young.

26.—[1901].—*Chætetes bed* is the source of splendid examples of the *Chætetes radians*. They are very large, and the sections, when polished, are exceedingly handsome. In the other beds the specimens are not nearly so fine.

Chætetes radians (Flem.); *Lithostrotion irregulare* (Edwds.).

27.—[1908].—*Comoides bed* is a black oolitic limestone, containing a great number of

Chonetes comoides (Fisch.); *Orthoceras Sp.* ?; *Producta Cora* (D'Orb.); *Alveolites septosa* (Edwds.)

[1910].—Another bed, similar to the last.

28.—[1916].—*Zaphrentis bed* is a dark coloured limestone, with very fine examples of *Zaphrentis Griffithsi* (Edwds.); *Amplexus coralloides* (Sow.); *Conocardium giganteum* (McCoy.).

29.—[1944].—*Gigantea bed,* so called from the enormous specimens of Producta gigantea found in a dark oolitic limestone.

30.—[1946].—*Foraminifera bed* is a good example of the fossil bed of an ocean. It is almost entirely made up of small foraminifera, shell-debris, echinus spines, &c.

31.—[1948].—*Irregulare bed* is a red limestone bed, very siliceous, and one mass of *Lithostrotion irregulare.*

32.—[1961].—A bed of limestone, containing very large specimens of *Euomphalus tuberculatus,* some of them being four inches in diameter.

33—[1968].—*Coral beds.* These are the principal coral bearing beds of the section, and contain a greater part of all the known species occurring in the locality.

Cyathophyllum regium (Phill.), *Stutchburyi* (Edwds.), *Murchisoni* (Edwds.); *Lithostrotion ensifer* (Edwds.), *Martini* (Edwds.), *basaltiforme* (Edwds.), *junceum* (Edwds.), *Lonsdaleia floriformis* (Edwds.), *Aulophyllum fungites* (Edwds); *Alveolites depressa* (Edwds.); *Clisiophyllum coniseptum* (Keys).

34.—*Plant bed.* This is a dark coloured oolitic bed, containing coal plants, with a large number of *Lithostrotion irregulare.*

35.—Is a light brown limestone, with very fine masses of *Cyathophyllum regium.*

36.—*Stigmaria bed.*

37.—*Murchisonia bed.* This, though disturbed, is evidently a continuation of the upper limestone series. It contains many univalves, which have, by many, been thought doubtful as Clifton specimens. It is a dark semi-crystalline limestone passing into one having a lighter colour. The fossils are very distinct from those found in previous beds.

Murchisonia angulata (Phill.); *Platyschisma tiara* (McCoy.), *Jamesoni* (McCoy.); *Naticopsis variata* (Phill.), *spirata* (McCoy.); *Loxonema rugifera* (Phill.); *Bellerophon apertus* (Sow.); *Conularia quadrisulcata* (Mill.); *Sedgwickia centralis* (McCoy.).

38.—*Orthoceras bed* contains weathered encrinites, and imperfect specimens of a large orthoceras.

39.—[2260].—*The Great Fault*, very properly so named, and is well worthy of a visit from every one studying the Clifton rocks. This spot bears most evident testimony to the great convulsive power that nature sometimes puts into action. Through the distance of 1090 feet, the ground is distorted and broken up in the utmost confusion, and the rocks twisted and overturned. The strata has been displaced to the extent of 800 feet vertically. One side upheaved, the other depressed and at the same time lateral pressure completed the destruction. Beds of coal mixed with millstone grit are side by side with mountain limestone, while the 500 feet of upper shales have been, as it were, buried out of sight, and the Avon gorge riven asunder. All these are open to the eye of the observer of the present day. So great was the disturbance of the country, that one half was turned one-fourth of the whole compass; the beds below the Great Fault dip to the S.S.E. 30°, while those above the Great Fault dip to the N.E. 70°. At the entrance to the tunnel, near the Clifton Station, coal beds may be seen, which have been buried 300 feet in the ground, while the same beds have, since that time, been entirely removed by denudation from the surface of the higher ground in the immediate neighbourhood. Complete evidence of lateral pressure may be seen by the curling of the marls and shales as they were forced against the massive beds of the St. Vincent's Rocks, which are only a repetition of the mountain limestone before described.

40.—A bed of gray limestone, containing *Terebratula hastata* (Sow.); *Syringopora geniculata* (Edw.).

41.—A bed of limestone, containing *Producta* and *Rhynchonella pugnus*.

42.—*Syringopora bed.*—A bed of limestone, containing the following corals. The last three beds are repetitions of those near No. 33.

Alveolites septosa (Edw.), *depressa* (Edw.); *Chœtetes radians* (Flem.); *Syringopora reticulata* (Goldf.), *lamellosa* (Edwd.), *geniculata* (Edwd.); *Lithostrotion junceum* (Edwd.), *affinis* (Edwd.); *Ptylopora frustraformis* (Phill.).

Near this spot, and a few feet before the next mentioned bed, is the long-famed Hotwell Spring, the water of which issues at the rate of 60 gallons per minute, at a tolerably uniform temperature of 70° Fahr. When freshly drawn, it is full of bubbles of Carbonic Dioxide and Nitrogen Gases, of which the late Mr. Herapath estimated that each gallon contained nearly 16 cubic inches. According to that chemist, analysis shewed that the water contained.

Chloride of Magnesium - - - -	2·180
Nitrate of Magnesium - - - -	2·909
Chloride of Sodium - - - -	5 891
Sulphate of Sodium - - - -	3·017
Sulphate of Magnesium - - - -	1·267
Carbonate of Calcium - - - -	17·700
Carbonate of Magnesium - - - -	·660
Carbonate of Iron - - - -	·103
Bitumen - - - - - -	·150
Sulphate of Calcium - - - -	9·868
Silica - - - - - -	·270
Total solid contents per gallon -	44·015 grains

43.—[2675].—*Solenopsis bed.*—It is now difficult to examine because it is not worked. It contains, however, many small corals, bivalves and univalves The principal fossil is the *Solenopsis minor*, which is tolerably plentiful and in good preservation.

44.—*Rhynchonella bed.*—This is a good fossiliferous bed, behind the Colonnade, and crops out again near the south buttress of the Suspension Bridge. The specimens of *Producta* and *Euomphalus* are larger here than in any other part.

Rhynchonella pugnus; Producta gigantea; *Euomphalus tuberculatus: Sanguinolites angustata*; *Myacites tumidus.*

45.—*Foraminifera bed.*—Although five good beds are known, yet this one is perhaps the best. It is oolitic in its structure, the granules being white, in a reddish brown matrix. It is impossible to cut a slide for the microscope without having three or four species of foraminifera on it. Almost every granule has for its nucleus a foraminifer or minute shell. Among others have been noticed the following genera—

Trochammina, Textularia, Climacammina, Stacheia, Endothyra. Lituola, Archædiscus, Valvulina, Nodosinella.

46.—Is a bed with abundance of *Terebratula hastata.*

47.—*Stutchburyi bed.* This is a very thick bed of brown limestone, full of larged sized corals, sufficiently perfect for the observation of all their anatomical details.

Cyathophyllum Stutchburyi (Edwd.), *regium* (Phill.); *Campophyllum Murchisoni* (Edwd.); *Lonsdaleia floriformis* (Edwd.); *Lithostrotion Martini* (Edwd.), *carnea* (Edwd.); *Mc Coyanum* (Edwd.)

48.—*Convoluta bed* is a reddish sandy limestone, very full of fossils, among which are *Spirifera convoluta* or *rhomboidalis* (Phill.); *Cyrtina septosa* (Dav.); *Producta Martini* (Sow.), *longispinosa* (Sow.). *Pinna*, sp ?; *Pecten*, sp ?; *Cochliodus contortus* (Ag.)

The five last beds are hidden by the houses, so that the examination must either be conducted by going through the gardens, or by finding them on the opposite side of the river.

On these lie the upper limestone shales, which are extremely sandy in their character, giving rise to the name of "Upper Grits." They are about 400 feet in thickness. They are not so rich in fossils as the other parts of the Clifton section, although 52 species have been noted.

[3045,]—This is the last of the Upper Shales, just below the

commencement of the Millstone Grit or farewell rock, the first bed of which may be seen behind the General Draper Inn. These beds are highly charged with Hematite. In some places the Ferric oxide is found as an amorphous deposit, containing from 40 to 50 per cent. of metallic iron. It is however, much mixed with silica, which consequently detracts from its value.

Perhaps a fair average of metallic iron would be about 30 per cent. Analyses of these Hematite ores from Clifton, Ashton, and Winford, chosen from the ordinary earthy samples, gave the following results.—

Ferric Oxide ...	75.19	72.00	85.00
Calcic Carbonate ...	3.54	2.16	1.01
Alumina	5.15	2.14	6.13
Silica	4.26	14.50	5.22
Manganese ...	trace	.21	.82
Phosphoric Acid ...	.01	.37	·25
Sulphur	.02	.03	trace
Moisture, &c. ...	11.83	8.59	1.57
	100.00	100.00	100.00
Metallic Iron ...	52.63	50.40	58.9

On the surfaces of some of the upper beds of siliceous limestone, or else enclosed in some of the larger crystals of quartz, are beautiful bright crystals of Hydrated Ferric Oxide (Göthite). On the beds near the southern buttress of the Suspension Bridge, are good specimens of Carbonate of Iron.

Good localities for collecting Carboniferous fossils are Cheddar, Portishead, Henbury, Weston, Clevedon, and many parts of the Mendip Hills.

The following is a list of the principal fossils that have been noticed in the Carboniferous rocks of the district.—

Felicites dichotoma
Knorria
Trochammina centrifuga (Brady)
    incerta (D'Orb)
Archædiscus Karreri (Brady)
Textularia eximia (D'Eichwold)
Climacammina antiqua (Brady)
Stacheia pupoides (Brady)
Lituola Binnicana (Brady)
Nodosinella concinna (Brady)

Endothyra Bowmani (Phill.)
ammonoides (Brady)
globulus (D'Eich)
ornata (Brady)
tenuis (Brady)
obliqua (Brady)
radiata (Brady)
Valvulina decurrens (Brady)
palæotrochus (Ehr)
v. compressa
Alveolites depressa (Edwd.)
septosa (Edwd.)
Chœtetes radians (Flem.)
Michelinia tenuisepta (Goldf.)
Syringopora reticulata (Goldf.)
lamellosa (Phill.)
geniculata (Phill.)
Campophyllum Murchisoni (Edwd.)
Cyathophyllum regium (Phill.)
Stutchburyi (E. & H.)
Murchisoni (E. & H.)
turbinatum (Goldf.)
Lonsdaleia floriformis (E. & H.)
Zaphrentis Griffithsi (E. & H.)
Amplexus coralloides (Sow.)
Lithostrotion ensifer (E. & H.)
Martini do.
Portlocki do.
irregulare do.
basaltiforme do.
junceum do.
concinnum do.
affine do.
carnea do.
MacCoyanum (Edwd.)
Aulophyllum fungites (E. & H.)
Clisiophyllum coniseptum (Keys.)
Cyathocrinus planus (Mill.)
Dichochrinus radiatus (Aust.)

Poteriocrinus conicus (Phill.)
crassus (Mill.)
isacobus (Austin)
plicatus do.
pentangularis (Mill.)
tenuis do.
rostratus (Austin)
Rhodocrinus costatus do.
granulatus do.
verus (Mill.)
Synbathocrinus conicus (Phill.)
Platycrinus covonatus (Goldf.)
granulatus (Mill.)
levis do.
Platycrinus rugosus (Goldf.)
striatus (Mill.
triginta dactylus (Austin)
tuberculatus (Mill.)
Actinocrinus aculeatus (Austin)
amphora (Goldf.)
cataphractus (Austin.)
elephantinas (Austin)
lœvissimus (Austin)
triacontadactylus (Mill.)
Pentremites globosus (Sow.)
Palœchinus
Serpula omphalodes (Goldf.)
Ceratiocaris
Leperditia Okeni (Muenst sp.)
var subrecta
Cythere oralis (n. sp.)
Cytherella lunata (n. sp.)
Phillipsia pustulata (Schloth)
Brongniarti (Fisch)
seminifera (Phill.)
Ptylopora pluma (McCoy.)
flustraformis (Phill.)
Fenestella flabellata (Lonsd.)
irregularis (Phill.)

polyporata (Portl.)
membranacea (Lonsd.)
Retepora prisca (Lonsd.)
Ceriopora interporosa (Goldf.)
rhombifera do.
Terebratula hastata (Sow.)
var ficus (McCoy.)
sacculus (Mont.)
vesicularis (DeKon)
Rhynchonella acuminata (Sow.)
pleurodon (Fisch.)
pugnus (Mart.)
Camarophoria globulina (King)
Spirifera cuspidata (Mart.)
Mosquensis (Fisch.)
convoluta var rhomboidea (Phill.)
lineata (Mart.)
bisulcata (Sow.)
glabra (Mart)
duplicicosta (Phill.)
striata (Mart.)
var attenuata
Cyrtina septosa (Dav.)
Athyris Royssii (Dav.)
lamellosa (L'Eo.)
Retzia radialis (Phill.)
Streptorhynchus crenistria (Dav.)
var arachnoidea (Dalm.)
Orthis resupinata (Mart.)
Michelini (L'Eo.)
Strophomena analoga (Phill.)
Productus scabriculus (Mart.)
Cora (D'Orb.)
Martini (Sow.)
longispinus (Sow.)
punctatus (Mart.)
giganteus (Mart.)
pustulosus (Phill.)
Chonetes comoides (Fisch.)
Sordida (Sow.)
papilionacea (Phill)
Hardrensis var perlata (Phill)
Buchiana (DeKon.)
Discina nitida (Lam.)
Lingula mytiloides (Sow.)
Pecten sp. (Br. Mus.)
Avicula Damnoniensis (McCoy.)
Aviculopecten granosus (Phill.)
fallax (McCoy.)
Pinna sp ? (Br. Mus.)
Modiola sp ? do.
Macadami (McCoy.)
var elongata
Cucullœa trapezium (McCoy.)
Hardingii (Sow.)
Conocardium giganteum (McCoy.)
Cypricardia rhombea (P. Mus. G.)
parallela (Phill.)
Sanguinolites angustata (Phill.)
complanata do.
transversa (Portl.)
Venus sp ? (Br. Mus.)
Pullastra perforans
Sanguinolaria sulcata (Phill.)
Solenopsis minor (McCoy)
Corbula Hennahii (Sow.)
Myacites tumida (Phill.)
Sedgwickia centralis (McCoy.)
Edmondia quadrata (Röm.)
Conularia quadrisulcata (Mill.)
Murchisonia spirata (Gold.)
angulata (Phill.)
Pleurotomaria biserrata (Phill.)
pygmœa (Stodd.)
canalienlata (McCoy.)
Platyschisma tiara (McCoy.)
Jamesii do.
Euomphalus tuberculatus (Flem.)
acutus (Sow.)
Calyx (Phill.)
nodosus (Sow.)

pileopsideus (Phill.)
Dionysii (Goldf.)
triangulatus (Stodd.)
Loxonema rugifera (Phill.)
Capulus vetustus (Mondf.)
Natica plicistria (Phill.)
variata (Phill.)
elliptica (Phill.)
Naticopsis spirata (McCoy)
Bellerophon apertus (Sow.)
Discites compressus (McCoy.)
Nautilus biangulatus (Sow.)
dorsalis (Phill.)
Orthoceras cinctum (Sow.)
gregarium do.
Breynii (Mart.)
Cyrtoceras sp ?
Amblypterus Portlocki (Egert.)
Cladodus Milleri (Ag.)
mirabilis do.
conicus do.

Deltoptychius acutus do.
Tomodus convexus do.
Chomatodus cinctus do.
linearis do.
Cochliodus contortus do.
Ctenacanthus brevis do.
minor do.
Ctenacanthus tenuistriatus do.
Helodus gibberulus do.
lœvissimus do.
subteres do.
turgidus do.
Onchus hamatus do.
sulcatus do.
Orodus cinctus do.
ramosus do.
Oracanthus Milleri do.
minor do.
pustulosus do.
Psammodus porosus do.
rugosus do.

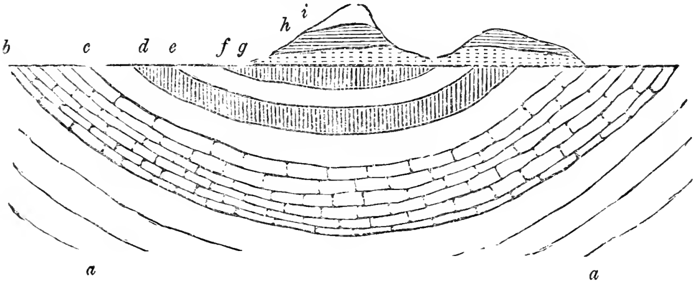
Geology of the Bristol Coal-field.

PART 4.—THE COAL MEASURES.

Read at the General Meeting, December 2nd, 1875.

WE now arrive at the most important of all our geological deposits—that useful mineral, Coal. Immediately upon the Upper Limestone shales we find a very thick deposit of Sandstones and beds of Coal of various thicknesses. They always appear in basin-shaped depressions, and in very regular layers, having a thickness of between 7000 and 8000 feet.

Fig. 18.—*Diagram of Bristol Coalfield.*



a Devonian—*b* Carboniferous Limestone—*c* Millstone Grit—*d* Lower Coal Measures—*e* Pennant Grit —*f* Upper Coal Measures—*g* Trias—*h* Lias—*i* Inferior Oolite.

On looking at our map, we find two or three of these Coal-basins near the surface of the ground, and some hidden from our view by several hundred feet of Triassic and Liassic strata. The longest of these is in Gloucestershire, twelve miles long and four wide. All over this field are extensive Collieries at Iron Acton, Coalpit-heath, Kingswood, Mangotsfield, and Fishponds.

Another Coalfield is on the south side of Dundry, about six miles in length and two in width, furnishing material at Pensford, Clutton, Paulton, Radstock, &c. A third division is that of Bedminster and Ashton, all of it being covered by the Lias.

A small Coal-basin is at Nailsea. It was formerly supposed to be merely a continuation of the Bedminster beds, but an examination of the surrounding Limestone is against this idea On every side the Limestone dips towards the centre of the basin, except on the west, where all the Limestone has been washed away by the waves of the sea. The deposit is small—only about three miles by one and a half. Here the Coal is worked both in the Pennant and Lower measures.

The borings and sinkings for the Severn Tunnel, prove that the Coal beds and Pennant grits extend under the Severn into Monmouthshire. Some thin seams of good Coal were extracted when making the shaft at Portskewet, containing numerous specimens of fossil ferns.

The entire Coal series may be well divided into four distinct parts, each lying within the other, and all in a basin-shaped cavity. The first being deposited immediately on the upper shales of the Carboniferous Limestone.

1.	Millstone Grit. ...	1000	feet in thickness.
2.	Lower Coal Measures	2000	,,
3.	Pennant Sandstone ...	1725	,,
4.	Upper Coal Measures...	3000	,,
		7725	

Millstone Grit.

The close of the Carboniferous period was marked by the surface of the land gradually rising, and a sandy deposit, formed by the disintegration of the Devonian rocks, so that the upper shales are easily distinguishable from the aluminous shales at the base of the Carboniferous rocks.

The Millstone Grit follows so gradually and conformably that it and the shales are sometimes undistinguishable. Generally speaking, the Millstone Grit beds are very thick and solid, as may be seen on the slopes of Brandon and Clifton hills. The Grit is formed of the hardest crystalline grains of sand, agglomerated with oxide of iron. In some places the iron is so abundant that the colour is a dark red, while in others it is a delicate pinkish grey. Some specimens are homogeneous, others are prettily striated. So hard are some beds, that they are preferred to Welsh Greenstone for paving stones where the traffic is heavy. Frequently the Devonian Mica is plainly visible. Sometimes a large percentage of limestone is met with, and most probably owes its presence to the shells of bivalves. In one of the lower Brandon-hill beds a large number of *Productæ* are seen, where the lime has totally disappeared, having been dissolved out, leaving a hollow cast of the shells. The Millstone Grit is not generally very fossiliferous, only a few beds in this neighbourhood being productive. Major Austin was fortunate enough to find a large number of mollusca and fish remains in one of the Tyndall Park beds, whence he obtained upwards of forty species. The only other localities that I have found to be fossiliferous have been on the north and south sides of the Avon, near Rownham ferry, the base of Brandon-hill, and near the fault in Leigh Woods.

The thickness of the Millstone Grit in this neighbourhood has been variously estimated. Mr. Etheridge puts it as 1200 feet, Mr. Anstie at 1000 feet, Professor Hull at 950 feet, while Major Austin estimates it at more than 2000 feet. From my own observations, I think 1000 feet is not far from the truth. However this may be, the Millstone Grit must have taken a very long period for its deposition. The regularity of the bedding, and the variation in the petrology and the occasional bands of limestone prove this. In the Millstone Grit are one or two seams of Coal, but quite unworkable.

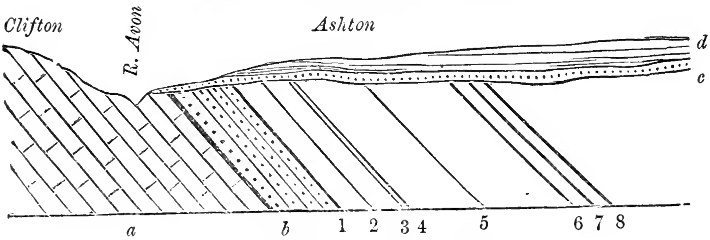
THE LOWER COAL MEASURES.

The Coal-bearing strata of this neighbourhood are divided into two sets, by an intervening band of grits called Pennant. The

Lower Coal Measures have an average thickness of 2000 feet; they lie an enormous depth from the surface, and can only be reached where they crop up. This will be at once evident by an examination of the diagrams. This remark is especially referable to the lowest seams. The principal collieries working this division of the Coal measures, are at Yate, Pucklechurch, Wapley, Cromhall, the north side of Kingswood, Fishponds, St. George's, Bedminster, Ashton, Nailsea, Holcombe, Vobster, and Ashwick.

At Bedminster the seam may be conveniently divided into two groups, the Bedminster and Ashton, the latter underlying the former.

Fig. 19.—*Bedminster Coal-field.*

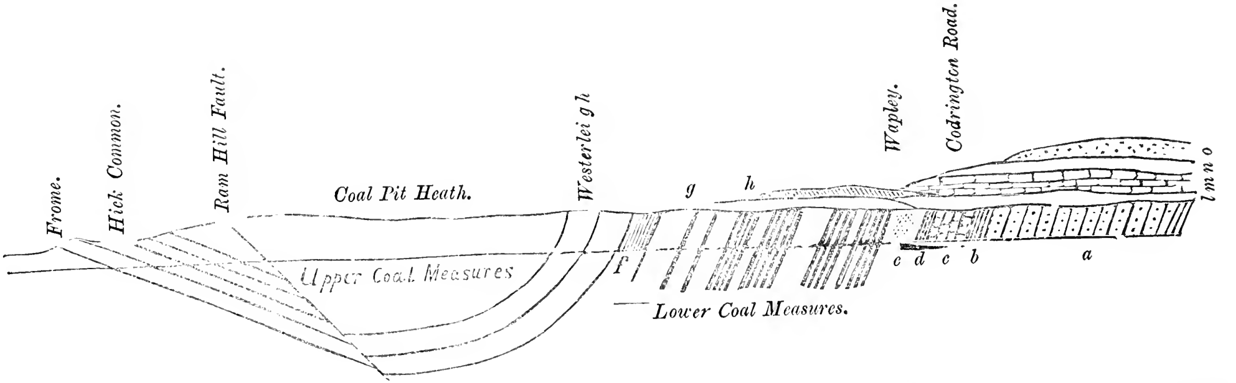


a Carboniferous Limestone—*b* Millstone Grit—*c* Magnesian Conglomerate—*d* Keuper

1. Little Vein.
2. Great Vein.
3. Top Vein.
4. Smith's Vein.
5. Toad Vein.
6. Bedminster Little Vein.
7. Bedminster Great Vein.
8. Bedminster Top Vein.

At Kingswood the lower Coal measures would not be workable if they had not been brought near the surface by a considerable upthrow, forming an anticlinal running in a S.W. direction from the West of Wick to the South of Fishponds. Till lately we supposed that all the possible seams had been reached, and that the Millstone Grit, or farewell rock appeared at Kingswood and of course prevented any possibility of going lower. However Mr. Cossham has proved that the supposed Millstone Grit is Pennant Sandstone that lies above instead of below the lower seams. The result is, that there remains a very extensive amount of Coal yet to be reached.

Fig. 20.—*Diagram of the Gloucestershire Coal-basin.*



a Devonian.—*b* Lower Limestone Shales.—*c* Carboniferous Limestone.—*d* Upper Shales.—*e* Millstone Grit.—*f* Pennant dividing Lower from Upper Coal Measures.—*g* Keuper.—*h* Rhætic.—*l* Lias.—*m* Marlstone.—*n* Upper Lias.—*o* Lias Sands.

Thirty-six seams of Coal are worked in the lower Coal measures. Westward of Cromhall the beds are entirely covered over by the new red. Here the upper Coal seam is 411 feet from the surface. At Kingswood the seams are very irregular from numerous faults and often rolled. In making the tunnel under the Severn the beds of shale and coal were found to be frequently upheaved from these undulations. At Bedminster and Ashton the seams come comparatively close to the surface. At Bedminster the first Coal seam is reached at 174 feet, and at Ashton at 270 feet. The Gloucestershire Coal-basin terminates here, being separated by an anticlinal limestone ridge, from a smaller basin at Nailsea. The probable thickness of the Nailsea Coal measures is about 1350 feet. The Coal unfortunately is very poor and sulphureous, and this, with an enormous influx of water, will, it is feared, stop any Coal mining in this basin.

South of the Mendip range, coal has been found, but the seams appear to have suffered from the violent disturbance which raised those hills and are "faulted" to a very large extent. Many of the seams give off fire damp. It is particularly troublesome at the Edford collieries. Here the disturbance has been so great, that the seams are nearly vertical. This is so at the Barton colleries also.

Mr. Anstie thinks, with great probability, that these now separate coal-fields were once continuous.

When the shaft at Portskewet for the tunnel was made, several thin seams of Coal from the lower measures were passed with very hard firestone. The coal was full of fragments of ferns.

As a rule, the Lower Coal Measures furnish a short list of plants whose names have been determined, but, probably, this entirely arises from want of a proper examination. Those that have been identified as having found in the lower seams, are so marked in the list of fossils at the end of this section.

Pennant Sandstone.

Upon the last of the Lower Coal Measure series, lies a mass of sandstone rocks 1725 feet thick. The Pennant grit is peculiar to our district, and is so similar to the coal shales, that the absolute division cannot always be positively stated. The beds are not visible in the southern portion of the coal-field, but come to the surface and afford excellent opportunities for inspection at Crew's Hole, Hanham, Stapleton, and Winterbourne. In the railway cutting at Mangotsfield station, an especially good section may be seen, containing traces of Coal. Between Mangotsfield and Winterbourne two seams of Coal have been worked.

Three of the Kingswood seams may almost be regarded as belonging to the Pennant.

At Stapleton, many fine specimens of trees have been found. A year or two ago the trunk of a Sigillaria elongata (Brong.) was exposed, 30 feet long, with both ends buried, so that the total length must have been great. The pennant is extensively quarried for building purposes, especially where large slabs are required. The steps in front of the Museum are Pennant, and are full of fossil wood.

At Nailsea the Pennant thins out, the total thickness being only about 450 feet. There a seam of Coal 3 feet thick occurs near the Church.

Pennant Sandstone often so nearly resembles Millstone Grit in its composition and structure, that it is quite impossible to distinguish them.

Five seams of Coal have been worked in the Pennant series, giving 10 feet of Coal.

In the Pennant, the following fossil plants have been collected.—

- Halonia irregularis (Lindl.)
- Ulodendron minus (Broug.)
  - majus (E. & H.)
- Knorria intricata (Sternb.)
- Calamites approximatus (Broug.)
  - arenaceus do.
  - cannœformis (Schl.)
  - Suckovii (Broug.)
- Sigillaria elongata do.
  - ornata do.

Dadoxylon approximatum (Williams)

UPPER COAL MEASURES.

We now come to the highest and last portion of the Coal Measures. Owing to their being so near the surface many of the seams have been washed away. They may be examined at Coalpit Heath, Parkfield, Westerleigh, Radstock, and Farringdon.

The Coal from the workable seams in Gloucestershire is of very good quality, some being highly bituminous. They are well adapted for gas and steam purposes.

From Brislington, southwards, the Coal measures are covered up completely by the New Red Marls, Lias, and inferior Oolite; after passing under Dundry Hill they emerge and come nearer the surface. At Clandown the shaft commences at the junction of inferior Oolite with the Upper Lias, and reaches the "Great" seam at the depth of 1212 feet. At Radstock the beds of Coal are thin, and necessitate the removal of an immense mass of useless shale.

The Upper Coal Measures have a total thickness of 3000 feet, and contain 22 workable seams of Coal with an aggregate thickness of 18 feet.

The Upper Coal Measures afford the most abundant supply of fossil plants, especially ferns. They are obtained from the shales overlying the Coal.

The following are the depths from the surface, to which shafts have to be sunk before reaching the first workable seam of Coal.

Easton	94	feet.	Malago	210	feet.
Kingswood	183	,,	Nailsea	330	,,
Newton St. Loe	300	,,	Parkfield	543	,,
Twerton	360	,,	Clandown	1212	,,
Ashton	270	,,	Camerton	690	,,
Bedminster	174	,,	Paulton	348	,,
Wapley	300	,,	Farringdon	198	,,

The faults are very numerous, and some of them very deep. They penetrate in every direction, and in various ways. The strata appear not only to have been severed by a down or up throw, but also subjected to enormous *side* pressure, for the Coal Measures in many places, as for instance from Patchway to Portskewet, assume the most extraordinary contortions and wave-like forms. The subterranean force that produced this, most probably happened when the Clifton chasm appeared. The great Avon fault shews great diagono-lateral pressure, and twisting the strike of the beds from N.E. and S.W. to N.W and S.E., thus turning the dip of the beds nearly a fourth of the compass.

A singular bed of Conglomerate 60 feet in thickness, intervenes between the "Polecat," and "Doxall" veins. It is composed of water-worn flint and other pebbles, and is cemented together with carbonate of lime. Among these pebbles are some curious light green ones, the exact nature of which is not quite clear. The most curious part of it is, that the very same kind of conglomerate occurs in the Worcestershire and Shropshire coal-fields. In each place the peculiar green pebbles occur, and the whole conglomerate is so closely alike, that it is quite impossible to distinguish the several specimens. A hard strong bed lies between this conglomerate and the "Doxall" seam, forming a good roof.

FORMATION OF COAL.

The microscopical and chemical examination of the several varieties of Coal shew most conclusively that it had a vegetable origin, and that it is the result of slow decomposition. That the trees grew where we find them is evident because on opening a Coal seam we find them in situ with the roots penetrating the ground in every direction.

In many places at the present day we find the counterpart of the old coal forest.

The well known Fern Creek at Dandenong in Australia is in a hollow and it generally happens in sub-tropical climes that these beautiful cryptogams prefer sheltered cavities where the decadent leaves falling from the stem, leaving the "scar," and perish on the damp ground; and all our carboniferous Coalfields are in the form of a series of hollows.

It is certain therefore that where we now find the Coal, was once a magnificent forest of Conifers and Treeferns 50 or 60 feet high, with a dense undergrowth of gigantic club mosses, growing in a dark and muddy swamp near the sea, and subject to an influx of the waves at high tides.

When a tree therefore was destroyed instead of lying exposed to the atmosphere and suffering the usual decomposition, it was at once buried in the mud and sand.

At the close of the carboniferous shales, as we before stated, the land was gradually rising, and after a very long period had passed, and sand had accumulated to the thickness of the millstone grit, a hollow creek appeared formed by a sluggish river, causing a kind of estuary. On this spot grew the rich growth of trees to which allusion has been made. After many years of luxuriance the land subsided a few feet and allowed the mud and sand to cover up the ground and destroy the vegetation. The leaves and broken bits of wood ground to pieces by the force of the water, got mixed with the sand, just as we now find them. The land again rose and and another forest was the result, which in its turn became engulfed. This is believed to be the explanation of the formation of the alternating beds of Coal and clays.

We always find that every Coal seam reposes on a bed of under clay. The Coal seam represents the vegetation while the under clay was the actual soil in which the plants grew. What was once a soft, oozy mud has been hardened by the lapse of ages, till now it is a hard stone and used for making the best firebrick.

After these changes had gone on for a long period of time, a great silting up with sand took place, forming what we know as the pennant sandstone. After a long continuance of sandy waste and another change of level, a second series of forests made their appearance in like manner until they in their turn were buried, in order to form a future storehouse of fuel beneath the conglomerates and sandstones of the Trias.

Coal is formed from slow oxidation of wood or cellulose aided by warmth and moisture, and the consequent evolution of marsh gas and carbonic acid, till practically nothing but carbon is left as in Anthracite; when this change has only partially taken place then we have *lignite*. The production of Coal from woody fibre, may be explained in four ways, either separately or all at the same time, the oxidation being varied under different circumstances.

1. By decomposition as Carbonic Acid and Water.
2. Do. do and Marsh Gas.
3. Do. Marsh Gas and Water.
4. Do. Carbonic Acid, Marsh Gas and Water.

The latter being the most probable. The production of two of our Coals from woody fibre, may be represented by the following formulæ—

NAILSEA COAL.

$$6\,\underset{\text{Cellulose}}{C_6H_{10}O_5} + 6\,\underset{\text{Oxygen}}{O_2} = \underset{\text{Coal}}{C_{22}H_{18}O} + 2\,\underset{\text{Marsh Gas}}{CH_4} + 12\,\underset{\text{Carbonic Acid}}{CO_2} + 17\,\underset{\text{Water}}{HO_2}$$

RADSTOCK COAL.

$$6\,\underset{\text{Cellulose}}{C_6H_{10}O_5} + 2\,\underset{\text{Oxygen}}{O_2} = \underset{\text{Coal}}{C_{26}H_{20}O_2} + 2\,\underset{\text{Marsh Gas}}{CH_4} + 8\,\underset{\text{Carbonic Acid}}{CO_2} + 16\,\underset{\text{Water}}{HO_2}$$

When wood has decayed, a small quantity of Humus is generally formed which has the peculiar property of absorbing Ammonia, and it is thus that the occurrence of Nitrogen in Coal is explained, The Sulphur exists as Iron-pyrites or Gypsum.

The following are analyses of a few specimens of Coal from the Gloucestershire and Somersetshire seams.

	Sp. Gr.	Carb,	Hyd.	Oxy.	Nit.	Sulph.	Ash.	Water.
Great Vein	1.30	84·46	5·17	3·03	1·01	1·16	3·67	1·50
Little Toad Vein	1·34	78·23	4·63	3.21	1·12	1·80	9·59	1·43
Upper 5 Coals	1·31	80·44	5·19	4·73	1·02	1·47	5·24	1·93
Coalpit Heath	1·31	83·28	5·17	3·04	1·16	·93	6·42	—
Holly Bush	1·33	74·24	5·68	6 16	·92	1·46	8 06	3·48
High Seam	1·31	78·72	5·42	4·59	1·27	1·07	6·92	2·01
Top Vein	1·30	79·99	5·77	5·85	1·22	1·08	4·08	2·01
Hard Vein	1·29	81·29	5·77	4·99	1·34	1·62	2·88	2·11
Toad Vein	1·29	80·99	5·31	4·27	1·18	1·24	5·38	1·63
Lower 5 Coals	1 34	80·33	5·63	3·07	1·44	1·31	7·14	1·18
Thurfer Vein	1·30	85·97	3·68	3·23	·82	1·83	3·46	1·01
Nailsea	1·31	81·21	5·81	4·98	1·04	2·85	3·00	1·11
Radstock	1·28	79·37	6·37	5·46	1·12	3·10	3·50	1·08

The above elements combine to form two classes of Hydrocarbons, one volatile and the other not·

A good gas Coal has a large proportion of volatile Hydrocarbon, while a good steam Coal has a large proportion of solid Carbon.

For example, the following are the natural arrangement in some of the samples mentioned in the foregoing table, and copied from Messrs. Cossham and Co.'s paper read at the British Association

Great Vein (Kingswood) a good Steam Coal—

Fixed Carbon ...	70·84
Volatile Matter ...	21·62
Ash	5·84
Water	1·50
	100·00

Hollybush Vein (a good Gas Coal)—

Fixed Carbon ...	59·10
Volatile Matter ..	34·97
Ash and Water ...	5·93
	100·00

When pure Coal is burnt the ash only contains a minute portion of Alkaline salts. The greatest part consists of Calcium, Magnesium, Aluminium, Iron, and Silica, most likely introduced with the coal by infiltration of water. As may easily be supposed the Coal in different parts of the same seam varies considerably, in one place burning freely and leaving little ash, while in another the percentage of mineral matter is so great that "slates" are produced which, when placed in an ordinary fire, explode and fly all over the room. These originate from the mud present in the original water in which the plants grew.

The formation of the Coal measures must have taken an enormous time, as the transition from wood to coal was necessarily very gradual and slow. An immense number of ages must have elapsed since the life and growth of the tree, and the product we now use, and upon which we so greatly depend.

Professor MacLaren (Geol. of Fife, 116,) calculates that it would require 1000 years to deposit sufficient material for a bed of Coal one yard thick. Now our Bristol Coal-measures without the Millstone Grit, have a thickness of 6725 feet of which only 100 feet are seams of Coal, the rest being sedimentary material which Professor MacLaren calculates was deposited at the rate of two feet per century.

It would follow from this that the Coal would take (100 or $33\frac{1}{3}$ yards × 1000,) 33,333 years and 6725—100 = 6625 feet and $\frac{6625 \times 100}{2} + 33,333 = 364,583$ years for the deposition of the whole Coal measures from the Millstone Grit upwards.

ESTIMATED THICKNESS OF THE COALFIELD.

Millstone Grit - - -	1000	feet.				
Lower Coal measures -	2000	with	36	seams of Coal	72	feet thick.
Pennant Grit - - -	1725	,,	5	,, ,,	10	,,
Upper Coal measure -	3000	,,	22	,, ,,	18	,,
	7725		63		100	

The quantity of Coal waiting for extraction is very large, Mr. Prestwich (Report Vol. 1. p. 50,) gives the following estimate of the future resources of the Bristol Coalfield, which was confirmed by Mr. Cossham at the last meeting of the British Association.

Quantity of Coal at a less depth than 1500 feet	= 1,718,791,280	tons
do. at a depth between 1500 & 3000 ,,	= 1,519,997,981	,,
do. do. do. 3000 & 6000 ,,	= 2,227,531,577	,,
do. do. do. 6000 & 8000 ,,	= 637,990,144	,,
Total	—6,104,310,982	tons

Now as Mr. Hunt says (Min. Stat. 1869,) that our annual output from 34 Collieries is 1,000,000 tons, it follows that our Coal supply is sufficient to last us 6000 years! In most specimens of our ordinary bituminous coal the vegetable structure is with difficulty examined by the microscope. Nothing but a black powdery mass of Carbon is seen which is perfectly opaque, so that the observer is greatly discouraged with his attempts to discover the woody fibre, medullary rays &c., so clearly described in all microscopical works.

It is only now and then that a good solid piece is found, that it is possible to satisfactorily make out the vegetable structure by section. The most successful way to proceed, that I have met with, is to soak a piece of the Coal for a week or two, in a tolerably strong solution of Potassium Carbonate (Pearlash,) then after washing well in distilled water, to gently warm the specimens in strong nitric acid till they change to a resinous brown color. They must then be sliced with a thin sharp knife and then be mounted in Canada balsam. On an examination of one of these sections, three kinds of substances will be seen—an opaque black carbon scarcely showing any structure, earthy matter slightly coloured, and a yellowish red semi-transparent portion shewing the medullary rays and fibres in the most beautiful manner. It is from this last ingredient that the gas is produced, so that the greater per centage of this there is in a sample of Coal, the more advantageous is its use for gas works.

The fossils that have been noticed in the Bristol Coal measures are Conifers, Ferns and Club mosses. The author has not met with a single mollusc or animal remains of any description except in the Millstone Grit, this is probably owing to want of opportunity for observation, as it is not likely so large an area of swamp as the original forest must have been, should have had no aquatic animals.

In the early part of this year Count Castracane of Rome, reported to Mr. Sorby that he had discovered Diatomaceæ in English Coal ashes. Mr. Sorby reports he had seen on these slides several well preserved species of Diatoms and also bodies like Xanthidia. I have searched most diligently the Coal ashes of our Coal field but quite unsuccessfully. The Count's Coal was shipped from Liverpool.

The "roofs" over the seams are the localities which furnish so many and beautiful varieties of the fern fronds. Some are very productive, as for instance the roof of the "Hard seam."

The following list of fossils, although imperfect, yet contains all that have been well ascertained to have been collected from the Coal seams of the Bristol District.

- Alethopteris Serlii (Brong.)
  - lonchitica (Sternb.)*
  - Mantelli (Brong.)
- Caulopteris Phillipsii (Lind.)
  - primœva do.
- Sphenopteris irregularis (Brong.)*
  - adiantoides do.
  - artemisiœfolia do
- Neuropteris acutifolia do.
  - acuminata do.
  - angustifolia do.
  - crenulata do.
  - flexuosa (Sternb.)
  - macrophylla (Brong.)
  - oblongata (Sternb.)
  - heterophylla (Brong.)*
- Pecopteris abbreviata do.
  - oreopteridis (Schloth.)*
  - arborescens (Brong.)
  - aspidioides do.
  - Bucklandi do.
  - Cistii (Brown)*
  - Meriani (Brong.)
  - plumosa do.
  - cyathea do.
  - crenulata do.
  - Miltoni do. *
  - dentata (Brown)
  - pteroides (Brong.)
  - villosa do.
  - æqualis do. *
- Aspidiaria anglica (Presl.)
- Aspidiaria confluens (Presl.)
- Lepidophloios laricinum (Sternb.)
- Ulodendron minus (Brong.)
  - majus (L. & H.)
  - Conybeari (Smith)
  - punctatum (L. & H.)
- Carpolithes alata
- Calamites approximatus (Brong.)
  - undulatus (Brong.)
  - cannæformis (Schl.)
  - Suckovii (Brong.)
  - Cistii do.
- Annularia fertilis (Sternb.)
  - longifolia (Brong.)
  - equisetifolia (Schloth.)
- Calamocladus equisetiformis do.
- Hippurites longifolius (Lind.)
- Sphenophyllum emarginatum (Brong.)
  - fimbriatum do.
  - Schlotheimii do.
- Sigillaria elegans do.
  - levigata do.
  - elongata do.
  - mammillaris do.
  - ornata do.
  - flexuosa do.
  - reniformis do.
  - scutellata do.*
  - tesselata (Sternb.)
- Dadoxylon approximatum (Williams)
- Lepidostrobus lepidophyllaceus (L.&H.)
- Trignocarpum Dawsii do.

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* Found in Lower Measures.

Classification of Professor RENEVIER compared with that of Sir C. LYELL.

PALÆOZOIC.											MESOZOIC OR SECONDARY.											CÆNOZOIC OR TERTIARY.									
LAURENTIAN.	CAMBRIAN		SILURIAN.		DEVONIAN			CARBONIFER'		PERMIAN	TRIAS			LIAS.			OOLITE.			CRETACEOUS.		EOCENE.			MEIOCENE.		PLEIOCENE.		POST-TERTIARY.		SIR C. LYELL, 1874.
Lower Upper	Lower	Upper	Lower	Upper	Lower	Middle	Upper	Lower	Upper		Lower	Middle	Upper				Lower	Middle	Upper	Neocomian Lr. Cretaceous	Upper Cretaceous	Lower	Middle	Upper	Lower	Upper	Older	Newer	Pleistocene	Recent	
Laurentian	Menevian Longmynd	Tremadoc Slates Lingula Flags	Bala & Caradoc Llandeilo Arenig	Ludlow Wenlock Llandovery	Lynton	Ilfracombe	Pilton	Mountain Lime-stone Carbonif Slate	Coal Measures Millstone Grit	Upper Permian Marl Slate Lower Permian	Bunter	[Muschelkalk]	Keuper	L. Lias	M. Lias	Upper Lias	Cornbrash, For Marble, Gt. Oolite, Stonsf. Slate Fuller's Earth Inferior Oolite	Oxford Clay Kelloway R. Coral Rag	Purbeck Portland Oolite Kimmer. Clay	Lower N. Middle N. Upper Neocomian	Gault Chalk Marl Chloritic series U. Chalk L. Chalk Maestricht Chalk	London Clay Reading, Thanet	Bagshot, Bracklesham	Bembridge, Osborne, and Headon series Barton Clay	Bovey Tracey Lignite Hempstead		Red Crag Coralline Crag	Bridlington beds Norwich Crag	Brixham Cavern Salisbury gravels Glacial Drift	Clyde Beds, &c.	
Laurentien	Menevion Huronien	Tremadocien Lingulien	Caradocien Llandeilien	Llandoverien Ledburien Ludlowien Wenlockien	Coblencien	Eifelien	Famennien	Culm Condrusien Ursien	Houiller	Thuringien Lodevien	Werfenien Poecilien	Virglorien	Larien Raiblien Halorien Œnien	Rhaetien Oxynotien Gryphitien Hettangien	Cymbien	Opalinien Thouarsien	Vesulien Bajocien Aalenien Bradfordien	Argovien Divesien Kellovien Sequanian Rauracien Glypticien	Purbeckien Portlandien Kimmeridgien	Valangien Hauterivien Aptien Rhodanien Urgonien	Vraconnien Albien Turonien Carentonien Rothomagien Danien Campanien Santonien	Londonien Thanetien	Bruxellien	Bartonien Sestien	Stampien Aquitanien	Tortonien Helvetien Langhein Œningien	Astien Plaisancien		Post-glaciaire Glaciaire Pre-glaciaire	Age du fer Age du bronze Age neolitique	PROF. RENEVIER, 1873-74.
PERIODE EOZOIQUE.	CAMBRIEN		SILURIEN	MURCHISONIEN	DEVONIEN			CARBONIFERE		PERMIEN	CONCHYLIEN		KEUPERIEN	RHÆTIEN SINEMURIEN	TOARCIEN		BATHONIEN	OXFORDIEN CORALLIEN	PORTLANDIEN	NEOCOMIEN URG.-APTIEN	GAULT CENOMANIEN SENONIEN	SUESSONIEN	PARISIEN	TONGRIEN	AQUITANIEN	FALUNIEN	SUBAPENNIN.		DILUVIEN	CONTEMPORAIN	
	PERIODE SILURIQUE.				P. CARBONIQUE.						P. TRIASIQUE.			P. LIASIQUE.			PERIODE JURASIQUE.			PERIODE CRETACE.		P. MUMMULITIQUE.			P. MOLASSIQUE.			P. ANTHROPIQUE.			
	ERE PRIMAIRE ou PALEOZOIQUE.										ERE SECONDAIRE ou MESOZOIQUE.											ERE CENOZOIQUE.									

On Professor Renevier's Geological Nomenclature and Table of Sedimentary Rocks.

BY E. B. TAWNEY, F.G.S.

Read at the General Meeting, April 1st, 1875.

THE object of these notes is to bring before the Society Professor Renevier's Table of Sedimentary Rocks, which, though printed in French, will be found, I think, of great use even to English students. In the first place, it forms a most convenient guide to refer to if one is seeking the place among English strata, or the equivalence of any foreign beds; and besides, it gives in a very compact form the leading fossils of the various divisions of sedimentary rocks. This it effects most conveniently from being printed in diagram form with parallel columns; *e.g.*, if we refer to the Carboniferous rocks we find, besides the column of leading fossils, &c , nine columns which give information on the presence or absence of the different sub-divisions of the Carboniferous epoch and peculiarities of local facies, with the local names used in those nine districts. In the case cited, the nine are—(i) England, (ii.) France and Belgium, (iii.) Germany, (iv.) Russia, (v.) North America, (vi.) Jura Mountains, (vii.) Italian Alps, (viii.) Western Alps, (ix.) Eastern Alps.

In glancing through this scheme of the well-known Professor of Geology in the Lausanne Academy, we cannot do better perhaps than follow the order of his own remarks in the explanation which he has printed in his native language. To begin with then, we must note that the diagram is printed in horizontal bands of different colours. There are nine of these bands, corresponding with the chief periods into which he divides the geological scale. These are the colours used by the Swiss Geological Commission, which is a body charged by the Federal Government with the execution of the geological map of Switzerland; and, therefore, as the table is designed, of course, primarily for his own countrymen, the compiler could not have done better than adopt the colours of the national map. Now Professor Renevier is one of the workers of the Federal survey and has just finished a sheet of part of the Western Alps, which will be a great boon to the visitors to the Bex Diablerets and Gruyere districts. He very justly remarks, therefore, that keeping the same conventional colours for both will much conduce to the rapid understanding of the maps. But he is perhaps a little sanguine in thinking that these colours are likely to be adopted by other nations. Of course, as the colours have been settled upon by the Federal Commission after, no doubt, mature consideration, we cannot presume to criticize them. Most of the colours of the English Geological Survey are, I think, admirably chosen, indicating very often the colour of the chief groups of beds themselves; *e.g.*, the Cretaceous with us is represented by various shades of green; it includes a great thickness of Greensand, and the Gault clay, which is a greenish blue; so are some of the Wealden beds. The Oolites are on our maps tinted yellow in different shades: this is the prevailing colour of the jurassic limestones with us. The Trias has a red colour, and very aptly for that is the chief tint of our New Red Sandstone and Bunter. The Coal Measures we represent by a diluted black; the Carboniferous Limestone is coloured bright blue, but this gives rise to little inconvenience in practice, though *a* blue (a different shade, however) is used by Limestone in the Silurians; and absolute regularity of shades is impossible, and very seldom do all the formations occur in the same sheet. The Old Red Sandstone has a darker shade of red. The Silurians are indicated by different shades of slate colour, the idea no doubt being taken from the colour of N. Wales roofing slates, the best slates coming chiefly from these older Palæozoic rocks.

It so happens that the Carboniferous rocks are the oldest known in Switzerland; there is, therefore, no colour settled by the Federal Commission for Silurian and Cambrian, &c., rocks. Professor Renevier has, therefore, had to chose one, and he has represented them by a pale crimson, which is used on their map for the crystalline schists and gneiss, his idea being that these may partly represent the missing older Palæozoic rocks.

So much for the conventional colours for geological maps, and for the significance of the coloured bands of which the diagram is composed. We must pay attention now to what the Professor calls the Hierarchy of the sub-divisions, for of this he makes rather a cardinal point. By this term is meant the different values given to words which denote divisions and sub-divisions, and so on. It is remarked, in zoology and botany there is a hierarchy of terms which are not allowed to be transposed; *e.g.*, Kingdom is a larger group than class, this than order, below which come family, genus, species: all these must be used in the proper order:—thus, an Order cannot be divided into classes,—the less into the greater; the word sub-order must be used if a sub-division is required. The rank of these words is universal and fixed in the sciences mentioned, but, as pointed out, is not so in geology. The words system, stage, group, or era, period, epoch, have quite different ranks attached to them by different authors; some divide a system into stages, others stages or formations into systems, and so on. It is held that this is very anomalous and should be rectified. Professor Renevier suggests that a set of words should be agreed upon which should everywhere, in geological use, have the same value. To begin with, he regrets as hierarchical terms the word *formation* (and in French the word *terrain*, also to which we have no exact equivalent in English) the former word being reserved to signify mode of formation; *e.g.*, marine, estuarine, &c. This is certainly to use the word in a more accurate way, and no doubt it would be well to follow his suggestion. We are, however, rather short of words to be applied to a mass of strata, and should be almost confined to the word *system*.

The hierarchical terms which the Professor proposes and uses in his table are these—

1.—Era .... *e.g.*, Tertiary or Cænozoic.
2.—Period .... ,, Nummulite.
3.—Epoch or System........... ,, Sub-apennine.
4.—Age or stage, horizon ...... ,, Astien

These words before they are generally adopted in a quasi-technical sense will of course be subjected to criticism; and we may venture to remark that there seems not quite enough difference in meaning between the words of the first column, which express the chronological point of view. We may suggest the word "Æon" as perhaps likely to be useful. Our terminology will still be defective because we have no words to express the former two divisions from a petrographical point of view. With respect to the word "system," we throughly approve of the place which is here given to it. Its connection with the Silurian epoch through the classical work of Murchison would compel us in England to restrict it to divisions of this rank and value. Professor Renevier remarks that in giving the word this value he has had to dethrone the "*étages*" of D'Orbigny, and make them take the lower place. Mr. K. Mayer also does the same. It would certainly be an improvement if geologists would follow our author's suggestion, and agree upon a definite hierarchy of words.

With respect to the nomenclature of the various sub-divisions and groups, Professor Renevier says that he has innovated as little as possible by usually adopting terms hitherto in use: even the words "gault" and "culm" are used, though they are incapable of taking the French adjective termination, and so agreeing with most of the other designations. The words "Keuper," "Ludlow," and "Caradoc," as applied to show a certain age of rocks, will be easily recognised in their French dress. Other examples of words which Professor Renevier has coined, though he deprecates their being called innovations, are "Gryphitien" for *Gryphæa arcuata* beds, "Opalinien" for *Amm. opalinus* beds. That he is no purist, is shown by his spelling the word Ludlowien, which stands for the

Ludlow rocks. The only two in the table which he admits to be entirely new, are those which he has introduced for the sub-divisions of the Permian, viz., "Thuringien" and "Lodevien:" the German terms "Zechstein" and "Rothliegende" are certainly very awkward.

The table contains all the synonyms or local names for the groups and divisions used in the different countries; they will be found in the columns under the heading of the country where they are used. This makes the table a most handy work of reference; suppose *e.g.*, that we wish to know the equivalent of the Werfen beds, we have only to glance down the column of the Alps till we come to them, and looking horizontally across the columns we see this equivalent in the different countries,—thus they correspond to the base of the Muschelkalk and are above the Bunter Sandstone.

In the Palæontological column the chief fossils of each group are given, and notes on the appearance and extinction of types of animals are added, *e.g.* the range of trilobites—the first appearance of Brachyurous Crustaceans, &c., may be here learned.

In the table here printed I have ventured to make an extraction from Prof. Renevier's table, taking therefrom the columns containing his terms, as well as Sir C. Lyell's grouping which is added for comparison. In the latter, however, I have made a few alterations, to bring it into accordance with later editions of Lyell's "Elements."

We may notice that the three great divisions or eras of column No. 1 agree with those of English, and I suppose most geological classifications for they are extremely natural: the change in life between the Palæozoic, Mesozoic, and Cenozoic is most distinctly marked. When we pass to column No. 2 of the rank of "periods," we find a divergence.

The first period "Anthropique" corresponds to the Quaternary of some authors; but Prof. R. rejects this word as this period is by no means equivalent to the Tertiary era, and there is no new flora and fauna; every one will agree in this, and we may be thankful to him for the term which signifies that the chief fact and interest in the period is the presence of man or his works. We miss the familiar Pliocene and Meiocene which are terms of less value than those used by Prof. Renevier in this column : they are both included in the period "Molassique." The Eocene shades off so through the Oligocene into [the Meiocene that it is impossible to draw hard lines between them, and therefore the grouping of this column may perhaps not be approved entirely. The next point in column No. 2 that we have to notice is the erection of the Lias into a period of the same rank as the Jurassic, and of a higher value than the Rhætic which is included in it. This is a great improvement on some classifications. Even in that of Prof. Morris and R. Jones* we notice that the Rhætic is made equivalent to the Lias: this seems to us very unfortunate, as in England these beds are not one tenth the thickness of the Lias, and are, palœontologically, mere passage beds between the Keuper and Lias—they may be placed under either of them, but are certainly equivalent to neither.

Below, in the column, we come to a period termed "Carbonique" which includes the Permian, Carboniferous, and Devonian: we are more accustomed here to the use of "Upper Palœozoic,"—a grouping which English authors will probably continue to use, though it does not follow that Carbonic is too like Carboniferous, or apt to promote misconception. One might even, perhaps, coin a word from some of the more common fossils of the period, such as *Sigillaria*, *Lepidodendron* or *Producta*. Perhaps more will be inclined to make objection to the period below, which is termed "Silurique:" we should almost like to restrict this word to the rank given it by Sedgwick or Lyell and other English authors who make it equivalent to, instead of including Cambrian. We shall prefer to use Lower Palœozoic to include this and the Laurentian, or as an equivalent to the professor's term, we might coin the word "Graptolitien" from a frequent fossil.

In glancing at the main groups of the first two columns we have deviated from the order of Prof. Renevier's explanation of the table, but for the remaining remarks we will read the table horizontally and so follow his text.

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* Synopsis of Lectures on Geology, 1870 (Van Voorst), by Professors Morris and T. Rupert Jones.

To return to the sub-divisions of the Tertiaries, the smaller of the Sub-apennine or Pleiocene epoch are taken from the names of places in Italy with rich fauna, showing different ages. The Œningen beds have, generally, been accounted U. Meiocene. Prof. R. remarks that his two periods in the Tertiary correspond with the Upper and Lower Tertiaries of Karl Mayer who is undoubtedly a great authority: still these two divisions are not separated by a hard line. If the geological record was complete there would perhaps be no lines to be drawn at all except conventional ones. In the L. Tertiary we find our London and Barton clays and Thanetsands giving names to three sub-divisions.

Professor R. has not divided the Cretaceous into Upper and Lower, though he admits it might be replaced by two periods; it has however been so divided by Lyell in later editions that the one cited and by other English authors. Remarks are made on the different values given to the Neocomien group; Professor R. uses the word in the more restricted sense and separates from it the Aptien, Rhodanien and Urgonien which are probably the equivalents of part of our L. Greensand beds.

The Jurassic group is divided after the manner usual in English classifications, into Lower, Middle and Upper. The Lower including the Bath freestone and accompanying beds from the so-called Inferior Oolite to the Cornbrash; the German method is to include the Lias in the Lower Jurassic, against which are many reasons. As Bradford-on-Avon is so near to us we are interested to notice that it forms one of the divisions of the fourth column, the Bradford Clay with us is a band less than 10 feet thick and therefore hardly worth making into a separate division; it may be considered as a clay band of the Forest Marble, a local feature; it is at the base where it does occur, and forms a convenient point of separation between the Bath Oolite proper and the Forest Marble, but its characteristic fossil Apiocrinus Parkinsoni is found equally in the Forest Marble, and the clay itself dwindles down to almost nothing in places. The Bradfordian of the Table however represents our Bath Oolite proper, Bradford Clay, Forest Marble and Cornbrash, altogether no great thickness with us; but of somewhat greater importance on the Continent. From an English point of view then it would seem more suitable to have used the word "Bathonian" here, taking it from the third column where it stands for our "Lower Oolite;" it must be confessed, however, that confusion may arise between the "Lower Oolite" and "Inferior Oolite" of English classifications. The arrangement of the Table is very clear and there is no inconsistency in using "Bathonian" as denoting all our Lower Oolites, for they all occur round the town of Bath; at the same time it is giving the word a wider acceptation than was given to it by D'Orbigny, but is at any rate preferable to the German use of the English word "Dogger" for the Lower Oolites.

Our "Inferior Oolite" so called is divided into two divisions supposed to correspond to the Murchisonæ and Humphresianus zones. With us the Parkinsoni zone is included in the Dundry or Inferior Oolite, being inseparably united with them and below the Fuller's Earth Rock, but according to the Table it ranges higher in some places (see column headed "French Alps.")

The top division of the Lias corresponds to our Midford or Upper Lias Sands, the former designation being much preferable to the latter, for it is still a question whether it is best classed with the U. Lias or Inf. Oolite. The palœntological affinities may be with the Lias, but the petrological characteristics are unquestionably rather those belonging to the Inf. Oolite. It would seem to be much the same in Suabia judging from the position given to the beds by Professor Quenstedt.

The Middle Lias is called "Cymbien" from *Gryphea cymbium* a leading fossil.

Professor Renevier some twelve years ago proposed the term "Hettangien" to represent the Planorbis beds; this is a most convenient expression and far preferable to the Infra-Lias of some authors; the beds well deserve the rank of a sub-division of the

Lias, for the fauna as a whole is very different from that of the Gryphæa beds.

The Rhætic is placed as the lowest division of the Lias; it will ever be an interesting page in geological history as it gives some hint of transition of the Trias into Lias. The Amphibian and Fish fauna of the older group is elbowed in our Aust Bonebed by the Ichthyosauri and Plesiosauri of the newer—reptiles at that time of the "coming race." The word Rhætien occurs in two columns of different values (so does Portlandien,) the Professor says that he was unable to avoid this; it may detract a little from the logical strictness of the Table but can have no practical inconvenience.

We may pass now to the Permian Epoch—under it the first thing that catches our eye is the "Dolomitic Conglomerate" of Bristol (there is a mark of interrogation however to it,) we are not surprised at this—it was so accounted once by the discoverers of the two reptiles found herein near Bristol. It is now however frequently called Bunter. There is no doubt however that it is not of Bunter age. Mr. W. Sanders, F.R.S. ¶ has shown that the Conglomerate is of no one precise age but occurs at any level in the N.R.S. (Keuper,) thinning out in one place and coming in again at a higher level. Latterly Sir C. Lyell has also placed it in the Keuper, * it is probably even partly as late as Rhætic age. It seems to lie above the Rhætic or be intercalated with it in places in S. Wales. Last year Mr. H. W. Woodward † intimated much the same thing from his survey of the Mendip district. Professor Morris and Rupert Jones ‡ class it as Keuper.

There is very little of the Palæozoic beds to be seen in Switzerland, the coal beds with fossil ferns occur near Bex, &c. Beyond this the table has to give us chiefly the groupings as developed in other countries. The Mountain Limestone figures under the name of "Condrusien:" it is well developed in Belgium, where Prof. De

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¶ Brit. Assoc. Rept. for 1849, p. 65.

* Students Elements of Geology, 2d. each, p. 111 and 361.

† Somerset Arch. and Nat. Hist. Soc. Proceedings for 1873.

‡ Synopsis of Lectures on Geology p. 71 (1870.)

Koninck divides it into an upper and a lower division. The Lower Limestone Shales and Calciferous Sandstones, &c., of Ireland are grouped under the name of "Ursien" from the locality of Bear Island, whence the fossil flora has been minutely described by Prof. Heer.

The classification of the Devonian agrees with that used in England. When we come to the Lower Palæozoic, of course the classification has to be taken entirely from England or N. America or Bohemia: Prof. Renevier has adopted mostly English names for the divisions of the fourth column.

We have before alluded to the use of the word Silurian and Silurique in different columns, the one made equivalent to our Lower Palæozoic, and the other about equal to the Lower Silurian of English authors, being opposed to the "Murchisonien" which stands for our Upper Silurian. If one part of the Silurian system is to be called after Murchison, perhaps the other might have been named after Sedgwick; that would have been one way of avoiding the double use of the same root. Lyell's arrangement of the Lower Palæozoic will be preferred by Englishmen probably. The table is based on the latest researches of Dr. Hicks as far as the subdivisions of the Cambrian is concerned.

We can see that there must have been an immense amount of work in drawing up this table of Sedimentary Rocks, from the quantity and compactness of the information which it conveys. A scheme too of this sort is very easy to refer to,—the eye catches the object sought at once, and the parallelism of the groups is better fixed in the memory after seeing them in tabular form than perhaps in any other way. We can therefore heartily recommend it to English students, more especially as there is no table published in England which includes nearly so many foreign groupings of beds.

List of Resident Birds, Summer and Winter Visitors, and occasional Stragglers, observed in the Bristol District.

BY E. WHEELER.

THE physical aspects of the Bristol district, consisting of open Downs, well wooded heights and valleys, rivers, streams, and muddy estuaries of the Avon and Severn, afford very favourable haunts for a considerable number of our indigenous birds, and summer and winter visitors. Although not so favoured as the east and south coast for Continental stragglers, yet at intervals we are visited by some few and attractive species.

The majority of our birds are of course arboreal. The sea coast with its granite, chalk, or limestone cliffs, the haunts and breeding places of the Colymbidæ, Alcadæ, and Laridæ, is beyond our limits, consequently members of these families form but a small part of our lists. The Steep Holm, in the Bristol Channel, is perhaps the nearest point where the common Sea Gull breeds. In the autumn and winter the banks of the Avon and Severn abound with them, as well as Black-headed, Herring, occasionally Great and Lesser Black backed Gulls, and Common Tern.

The absence, too, of extensive and unfrequented Marsh lands, the natural habitat of the Scolopacidæ and Anatidæ permits us to number but a few of these interesting families, most of the species of which are uncommon.

Thirty years since our British birds numbered about 320 species. About 73 have since been discovered, making up to the present time 393 species. Of these the Bristol district includes about 108 residents, 37 summer, and 27 winter visitors, including a few rare stragglers, numbering altogether 167 species.

The *Falconidæ* form but a very small group. The "Honey Buzzard" has been twice killed at Leigh; specimens also of the "Common Buzzard" have been shot, and the "Kite" once. The "Hobby" and "Merlin" are the only others of sufficient rarity to need notice; it is many years, however, since either have been observed.

The *Strigidæ* are represented by the two ordinary species, the Brown and Barn Owl. The short and long-eared species are both rare.

None of the *Laniadæ* have been noticed, excepting our ordinary summer visitor, the Red-backed Shrike.

Amongst the small group of the *Muscicapidæ* only the Pied Fly-catcher need be mentioned as being of great rarity, having occurred once only.

The ordinary species of the *Merulidæ* are well-known resident or winter visitors. The Ring Ousel is a scarce summer visitant.

Amongst the *Sylviadæ* no species have been observed requiring any special remark. The Reed, Sedge, and Grasshopper Warblers are all uncommon. Nightingales have been these last two or three years much more numerous. The Bearded and Crested Titmice are both absent from the *Paridæ*. All the others are tolerably common, *P. Major* and *Cæruleus* especially so. The one representative of the *Ampelidæ*, the Waxwing, has occurred at rare intervals.

The common species of the *Motacillidæ*, *Anthidæ*, and *Alaudidæ* are all pretty generally distributed, the "Rock pipit" being the only really local bird. The rare visitor, *A. alpestris*, the Shore

Lark, was captured by a birdcatcher in the neighbourhood in 1873, and exposed for sale with Yellowhammers; it was, I believe, purchased for a shilling, and given to the Zoological Gardens, in whose aviary it is still retained.

In the *Emberizidæ* we have one rare winter visitor, the Snow Bunting, which has been shot at Avonmouth; the Cirl Bunting, occurs occasionally. The *Fringillidæ* are very well represented. The Brambling is local; also the Tree Sparrow. Haw Finches have these last two or three winters been more abundant, remaining till late in the spring. Many breed here; at Henbury, and near Almondsbury, nests and eggs have been taken. The Mountain Linnet is a rarity; as also the Crossbill; both have occurred at Leigh and Henbury. We have another rarity in the family *Sturnidæ*, the "Rose-coloured Pastor:" this has been once shot in the vicinity. The *Corvidæ* all belong to us with the exception of the Chough. The Hooded Crow and the Raven are both rare. The families forming the group of *Scansores* call for no special remarks, except the occurrence of the Hoopoe some years since, both Great and Lesser Spotted Woodpeckers are uncommon. Another rare straggler, the Bee Eater, visited Stapleton a few years ago. Several specimens were seen by Mr. G. Harding frequenting the beehives in his grounds, three of which were shot by him.

The Kingfisher may be found in several parts of the neighbourhood. The *Hirundinidæ* and *Caprimulgidæ* are each represented by the generally distributed species known almost everywhere: so also with the *Columbidæ* and *Phasianidæ.* Two species of the *Tetraonidæ*, the Black and Red Grouse, have been shot, but of great rarity. The Quail is another rare visitant. The *Charadriidæ* and *Ardeidæ* families are not numerous, the commoner species only have hitherto been noticed, with the exception of the Bittern, which has been shot near Portishead and Clevedon. Amongst the *Scolopacidæ* too we number but a few, the Green Sandpiper perhaps being the rarest. The Whimbrel, Bartailed Godwit, and Redshank are occasional visitors. The Spotted Crake and Grey Phalarope are rare members of the next two families, occasionally occurring. The remaining group of the *Natatores*, comprising the Ducks, Divers, and Gulls, &c., leave little to remark, a few are common; the chief rarities hitherto noted have been the Canada Goose, Shoveller, Scaup Duck, and Goosander, amongst the *Anatidæ*, and the Great Northern Diver, two of which were shot in the Floating Harbour, amongst the *Colymbidæ*. The common species of the *Alcadæ*, the Guillemot and Razor Bill, are with us only occasional visitants. The Cormorant and Shag are also occasionally met with off Weston-super-mare. The only rarities amongst the *Laridæ* is the Little Gull, shot in 1850 at Portishead. The Stormy Petrel has occurred there also, but these waifs and strays from the open sea are but accidental visitors, there being so little congenial to their habits in the muddy waters of the Severn.

In compiling the following List, I have to acknowledge the kind assistance given by the Rev. Marcus Richards, Mr. Geo. Harding, and Mr. C. Charbonnier, without whose help most of the rarer species would have been absent.

Order 1. RAPTORES.
Family. FALCONIDÆ.
Genus. *Falco.*

Falco abicilla - White Tailed Eagle - Indigenous - very rare
(One shot in Doddington Park, Gloucestershire. Date not known. Rev. M. R.)

F. peregrinus - Peregrine Falcon - Indigenous - very rare
(Shot some years ago. Date not known. G. H.)

F. subbuteo - Hobby - Summer visitor - occasional
(First occurred some years ago. A very fine example caught by a birdcatcher a few weeks since; in Mr. G. Harding's possession. Preserved by Mr. Charbonnier. These birds are captured in this way as often as shot. G. H.)

F. æsalon - Merlin - Summer visitor - occasional

(Two or three have been shot at intervals. No record.)

F. tinnunculus - Kestrel - Summer visitor - generally distributed

(Frequent occurrence. Breeds at Leigh, and a year or two since in St. Vincent's Rocks.)

F. nisus - Sparrow Hawk - Summer visitor - generally distributed

(Frequent occurrence. Breeds at Leigh and Henbury. Becoming scarce, from continual destruction.)

Falco milvus - Kite - Indigenous - rare

(One shot some years since. No record.)

F. buteo - Buzzard - Indigenous - rare

(Two shot at Leigh. One in my possession.)

F. apivorous - Honey Buzzard - Indigenous - rare

(Two at Leigh. No record of date. G. H.)

F. cyaneus - Hen Harrier - Indigenous - rare

(Has occurred some years since. No record. G. H.)

Family. Strigidæ.
Genus. *Strix.*

Strix otus - Long-eared Owl - Indigenous - rare

(Portishead. Local list.)

S. brachyotus - Short-eared Owl - Indigenous - occasional

(Leigh. Portishead.)

S. flammea - White Owl - Indigenous - generally distributed

(Leigh. Kingsweston. Not common.)

S. aluco - Brown Owl - Indigenous - generally distributed

(Leigh; Stoke Bishop; Stapleton; Kingsweston,)

Order 2. INSESSORES.
Group 1. Dentirostres.
Family. Laniadæ.
Genus. *Lanius.*

Lanius collurio - Red-beaked Shrike - Summer visitor - gen. dis.

(Frequent at Leigh, Hallen, Stapleton. Insects some times found impaled by this bird.)

Family. MUSCICAPIDÆ.
Genus. *Muscicapa.*

Muscicapa grisola - Spotted Fly Catcher - Summer visitor - gen. dis.
(Frequent at Leigh Woods; Orchards, Gardens, and Plantations.)

M. atricapillæ - Pied Fly Catcher - Summer visitor - rare
(One only at Ashton, many years since.)

Family. MERULIDÆ.
Genus. *Turdus.*

Turdus viscivorus - Missel Thrush - Indigenous - tolerably common
Frequent on Downs and Leigh.

T. pilaris - Fieldfare - Winter visitor - abundant
(Commoner some winters than others.)

T. musicus - Song Thrush - Indigenous - abundant
(Well-known everywhere.)

T. iliacus - Redwing - Winter visitor - abundant
(More numerous than Fieldfares, and usually arrives earlier.

T. merula - Blackbird - Indigenous - abundant everywhere
(Pied varieties occasionally occur.)

T. torquatus - Ring Ousel - Summer visitor - rare
(Occurs occasionally at Leigh Woods and Stapleton. G. H.

Family. SYLVIADÆ.
Genus. *Accentor.*

Accentor modularis - Hedge Sparrow - Indigenous - com. everywhere

Genus. *Sylvia.*

Sylvia rubecula - Robin - Indigenous - common everywhere

S. phœnicurus - Redstart - Summer visitor - abundant

S. rubicola - Stonechat - Indigenous - local
(Not very common. Downs; Ashton; Leigh.)

S. rubetra - Whinchat - Summer visitor - local
(Not common. Ashton; Leigh.)

S. œnanthe - Wheatear - Summer visitor - generally distributed
(Downs; Leigh; Avonmouth.)

S. locustella - Grasshopper Warbler - Summer visitor - not com.
(Seldom seen, from its shy habits. Sometimes heard. Leigh; Portishead; Knowle.)

S. phragmites - Sedge Warbler - Summer visitor - very local
(Near Nailsea; Stapleton.)

S. arundinacea - Reed Warbler - Summer visitor - very local
(Stapleton, occasionally,)

S. luscinia - Nightingale - Summer visitor - generally distributed
(In Woods. Commoner than formerly. Clifton Down; Leigh.)

S, atricapilla - Blackcap - Summer visitor - generally distributed
(May be heard almost everywhere.)

S. hortensis - Garden Warbler - Snmmer visitor - generally dis.
(Plantations, Gardens, &c. Less frequent than preceding.)

S. cinerea - White Throat - Summer visitor - generally dis.

S. curruca - Lesser do. - Summer visitor - not common

S. sibilatrix - Wood Wren - Summer visitor - tolerably common
(In Woods.)

S. trochilus - Willow Wren - Summer visitor - local, not common
(Stapleton; Ashton.)

S. rufa - Chiff-Chaff - Summer visitor - abundant

Genus. *Regulus.*

Regulus Cristatus - Gold Crested Wren - Indigenous - gen. dis.
(Woods, Plantations.)

Family. PARIDÆ.

Genus. *Parus.*

Parus major - Great Titmouse - Indigenous - abundant everywhere
(Woods, Gardens, &c.)

P. cœrulus - Blue Titmouse - Indigenous - abundant everywhere
(Woods, Gardens, &c.)

P. ater - Cole Titmouse - Indigenous - local
(Leigh Woods; Stapleton.)

P. palustris - Marsh Titmouse - Indigenous - generally distributed

P. caudatus - Long-tailed Titmouse - Indigenous - tolerably common

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Family. AMPELIDÆ.
Genus. *Bombycilla.*

Bomb. garrula - Bohemian Waxwing - Winter visitor - very rare
(Has occurred at intervals. Ashton.)

Family. MOTACILLIDÆ.
Genus. *Motacilla.*

Motacilla alba - White Wagtail - Indigenous - rare
(Durdham Down; Leigh Woods. Rev. M. R.)

M. Yarrelli - Pied Wagtail - Indigenous - abundant everywhere

M. boarula - Grey Wagtail - Indigenous - not common
(Chiefly seen in winter.)

M. flaveola - Ray's Wagtail - Summer visitor - local
(But not uncommon where it occurs. Clifton Down; Avonmouth; Ashton; Stapleton.)

Family. ANTHIDÆ.
Genus. *Anthus.*

Anthus arboreus - Tree-pipit - Summer visitor - tolerably common

A. pratensis - Meadow-pipit - Indigenous - very common
(Leigh; Clifton; Avonmouth; Sea Mills.)

A. aquaticus - Rock-pipit - Indigenous - local, but tolerably common
(Banks of Avon.)

Group 2. Conirostres.
Family. Alaudidæ.
Genus. *Alauda.*

Alauda arvensis - Skylark - Indigenous - abundant

A. arborea - Woodlark - Indigenous - local
(Leigh; Shirehampton.)

A. alpestris - Shore Lark - Occasional visitor - very rare
(One caught near Bedminster, by a birdcatcher.)

Family. Emberizidæ.
Genus. *Emberiza.*

Emberiza nivalis - Snow Bunting - Winter visitor - very rare
(Two or three times at Avonmouth.)

E. miliaria - Common Bunting - Indigenous - generally distributed
(Not common.)

E. schœniclus - Black-headed Bunting - Indigenous - local
(Not common. Stapleton; Avonmouth.)

E. citrinella - Yellowhammer - Indigenous - abundant

E. cirlus - Cirl Bunting - Indigenous - rare
(Has occurred at Wrington.)

Family. Fringillidæ.
Genus. *Fringilla.*

Fringilla cœlebs - Chaffinch - Indigenous - abundant everywhere

F. montifringilla - Brambling - Winter visitor - local
(Occurs some years in tolerable abundance. Stapleton.)

F. montana - Tree Sparrow - Indigenous - rare

F. domestica - House Sparrow - Indigenous - common everywhere

F. chloris Greenfinch - Indigenous - abundant

F. coccothraustes - Hawfinch - Winter visitor - local
(Occurs every winter on Clifton and Durdham Downs, and Henbury. Some remain to breed.)

F. carduelis - Goldfinch - Indigenous - local
(Much less frequently seen than formerly.)

F. spinus - Siskin - Winter visitor - local
(Occurs most winters at Stapleton and Leigh.

F. cannabina - Linnet - Indigenous - common

F. linaria - Lesser Redpole - Indigenous - tolerably common
(Leigh Woods and Stapleton.)

F. montium - Twite - Indigenous - rare
(Occasionally at Leigh.)

Genus. *Pyrrhula.*

Pyrrhula vulgaris - Bulfinch - Indigenous - tolerably common
(Clifton Down and Leigh.)

Genus. *Loxia.*

Loxia curvirostra - Crossbill - Winter visitor - rare
(Occasionally. Henbury.)

Family. Sturnidæ.
Genus. *Sturnus.*

Sturnus vulgaris - Starling - Indigenous - common everywhere

Genus. *Pastor.*

Pastor roseus - Rose-coloured Pastor - Summer visitor - very rare
(One shot at St. Philip's Marsh. G. H.)

Family. Corvidæ.
Genus. *Corvus.*

Corvus corax - Raven - Indigenous - rare
(Occasionally at Leigh and Stapleton.)

C. corone - Crow - Indigenous - local
(Common on banks of Avon.

C. cornix - Hooded Crow - Indigenous - rare
(Has occurred once or twice, but no exact locality known.)

C. frugilegus - Rook - Indigenous - common everywhere

C. monedula - Jackdaw - Indigenous - common
(St. Vincent's Rocks and Leigh.)

C. pica - Magpie - Indigenous - generally distributed

C. glandarius - Jay - Indigenous - common in woods

Group 2. SCANSORES.
Family. PICIDÆ.
Genus. *Picus.*

Picus viridis - Green Woodpecker - Indigenous - generally dis.
(Leigh; Clifton Downs; Stapleton; Ashton,)

Picus major - Great spotted Woodpecker - Indigenous
(Occasionally met with. Leigh; Ashton.)

P. minor - Lesser spotted Woodpecker - Indigenous
(Occasionally met with. Leigh; Ashton.)

Genus. *Yunx.*

Yunx torquilla - Wryneck - Summer visitor - generally distributed

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Family. CERTHIADÆ,
Genus. *Certhia.*

Certhia familiaris - Creeper - Indigenous - tolerably common
(Everywhere.)

Genus. *Troglodytes.*

Troglodytes vulgaris - Wren - Indigenous - common
(Everywhere.)

Genus. *Upupa.*

Upupa epops - Hoopoe - Straggler - very rare
(Two individuals shot some years since.)

Genus. *Sitta.*

Sitta Europæa - Nuthatch - Indigenous - tolerably common
(In woods.)

Family. CUCULIDÆ.
Genus. *Cuculus.*

Cuculus canorus - Cuckoo - Summer visitor - common
(In woods and parks.)

Group 4. FISSIROSTRES.
Family. MEROPIDŒ.
Genus. *Merops.*

Merops apiaster - Bee-eater - Summer visitor - very rare
(Several shot a few years since by Mr. G. Harding, Stapleton. Frequenting beehives in garden.)

Family. HALCYONIDŒ.
Genus. *Alcedo.*

Alcedo ispida - Kingfisher - Indigenous - local, not common
(Stapleton; Ashton; Avonmouth; Sea Mills.)

Family. HIRUNDINIDŒ.
Genus. *Hirundo.*

Hirundo rustica - Swallow - Summer visitor - common
(Everywhere.)

H. urbica - Martin - Summer visitor - common
(Everywhere.)

H. riparia - Sand Martin - Summer visitor - local
(Stapleton.)

Genus. *Cypselus.*

Cypselus murarius - Swift - Summer visitor - generally distributed

Family. CAPRIMULGIDŒ.
Genus. *Caprimulgus.*

Caprimulgus Europœus - Nightjar - Summer visitor
(Generally distributed in woods.)

Order 3. RASORES.
Family. COLUMBIDŒ.
Genus. *Columba.*

Columba palumbus - Ring Dove - Indigenous - generally distributed
(Woods and copses.)

C. œnas - Stock Dove - Indigenous - generally distributed
(Woods.)

C. turtur - Turtle Dove - Summer visitor - not common
(Leigh.)

Family. PHASIANIDÆ.
Genus. *Phasianus.*

Phasianus colchicus - Pheasant - Indigenous - abundant
(Woods and preserves.)

Genus. *Tetrao.*

Tetrao tetrix - Black Grouse - Indigenous - occurs occasionally
(Portishead; Mendip Hills.)

T. scoticus - Red Grouse - Indigenous - occurs occasionally
(Mendip Hills.)

Genus. *Perdix.*

Perdix cinerea - Partridge - Indigenous - generally distributed

P. coturnix - Quail - Summer visitor - rare
(Stapleton. G. H.)

Order 4. GRALLATORES.

Family. Charadriidæ.

Genus. *Charadrius.*

Charadrius pluvialis - Golden Plover - Indigenous - occasionally
(Banks of river.)

C. hiaticula - Ringed Plover - Indigenous - common
(Banks of Avon and Severn.)

C. morinellus - Dotterell - Indigenous - rare
(Flat Holmes. G. H.)

Genus. *Vanellus.*

V. cristatus - Lapwing - Indigenous - common
(Leigh; Portishead; Failand.)

V. melanogaster - Grey Plover - Indigenous - occasionally
(Avonmouth.)

Genus. *Strepsilas.*

S. interpres - Turnstone - Indigenous - rare
(Avonmouth; Portishead.)

Genus. *Calidris.*

C. arenaria - Sanderling - Indigenous - rare
(Near Clevedon.)

Genus. *Hæmatopus.*

H. ostralegus - Oyster Catcher - Indigenous - occasionally
(Banks of Severn.)

Family. Ardeidœ.

Genus. *Ardea.*

A. cinerea - Heron - Indigenous - not uncommon
(Banks of Severn; occasionally on Avon; and Leigh;)
Abbot's Pond.)

A. stellaris - Bittern - Summer visitor, sometimes resident - rare
(Near Clevedon and Portishead.)

Family. Scolopacidœ.
Genus. *Numenius.*

N. arquata - Curlew - Indigenous - common
(Avonmouth; Portishead.)

N. phœopus - Whimbrel - Indigenous - local
(Occasionally seen, Portishead; Avonmouth. Rev. M. R.)

Genus. *Totanus.*

T. calidris - Redshank - Indigenous - occasionally occurs in winter
(Avonmouth.)

T. ochropus - Green Sandpiper - Summer visitor - rare
(Near Yatton. G. H.)

T. hypoleucos - Common Sandpiper - Summer visitor - occasional
(Portishead; Banks of Avon.)

Genus. *Limosa.*

L. rufa - Bar-tailed Godwit - Winter visitor - occasional
(Portishead.)

Genus. *Scolopax.*

L. rusticola - Woodcock - Indigenous - not uncommon
(Leigh; Henbury; Durdham Down, occasionally.)

S. gallinago - Common Snipe - Indigenous - not uncommon
(In marshy places; Portishead; Durdham Down; Stapleton.)

S. gallinula - Jack Snipe - Winter visitor - occasional
(In marshy places; Ashton; Clevedon.)

Genus. *Tringa.*

T. variabilis - Dunlin - Indigenous - common
(Banks of Avon and Severn.)

Family. Rallidæ.
Genus. *Gallinula.*

G. crex - Landrail - Summer visitor - common
(In fields generally.)

G. porzana - Spotted Crake - Summer visitor - rare
(Ashton.—C. C. Stapleton.—G. H,

G. chloropus - Moorhen - Indigenous - common
(Ashton; Stapleton: Leigh; Avonmouth; Henbury.

Genus. *Rallus.*

R. aquaticus - Water Rail - Indigenous - occasional
(Ashton; Stapleton.)

Family. Lobipedidæ.
Genus. *Fulica.*

F. atra - Coot - Indigenous - rare
(Near Clevedon. G. H.)

F. platyrhyncus - Grey Phalarope - Winter visitor - rare
(Clevedon. Rev. M. R.

Order 5. NATATORES.
Family. Anatidæ.
Genus. *Anser.*

Anser ferus - Grey-legged Goose - Winter visitor - rare
(Avonmouth,)

A. segetum - Bean Goose - Winter visitor - occasional
(Avonmouth.)

A. bernicla - Brent Goose - Winter visitor - rare
(Avonmouth.)

A. Canadensis - Canada Goose - Winter visitor - rare
(One shot some years since.)

Genus. *Cygnus.*

C. musicus - Hooper Swan - Winter visitor - rare
(Avonmouth.)

Genus. *Anas.*

A. tadorna - Common Shieldrake - Indigenous - not uncommon
(Banks of Severn; Barrow. G. H.)

A. clypeata - Shoveler - Winter visitor - rare
(Portishead.)

Anas acuta - Pin-tailed Duck - Winter visitor - rare
(Avonmouth. Rev. M. R.)

A. boschas - Wild Duck - Indigenous - not common
(Ponds and Marshes.)

A. crecca - Teal - Indigenous - rare
(Clevedon; Portishead.)

A. penelope - Widgeon - Winter visitor - rare
(Portishead; Ashton.)

A. perspicillata - Surf Scoter - Winter visitor - rare
(Ashton. Rev. M. R.)

A. ferina - Pochard - Winter visitor - occasional
(Nailsea.)

A. marila - Scaup Duck - Winter visitor - rare
(Portishead. G. H.)

A. clangula - Golden Eye - Winter visitor - rare
(Near Banwell. Rev. M. R.)

Genus. *Mergus.*

M. merganser - Goosander - Winter visitor - rare
(Wraxall. G. H.)

Family. COLYMBIDÆ.
Genus. *Podiceps.*

P. minor Little Grebe - Indigenous - occasional
(On the Avon.)

Genus. COLYMBUS.

C. glacialis - Great Northern Diver - Winter visitor - very rare
(Two specimens in Floating Harbour some years since.)

Family. ALCADÆ
Genus. *Uria.*

U. troile - Guillemot - Indigenous - occasional
(Weston-super-Mare. C. C.)

Genus. *Alca.*

A. torda - Razor Bill - Indigenous - occasional
(Weston-super-Mare. C. C.)

Family. PELECANIDÆ.
Genus. *Carbo.*

C. cormoranus - Cormorant - Indigenous - occasional
(Weston-super-Mare. C. C.)

C. cristatus - Shag - Indigenous - occasional
(Weston-super-Mare. C. C.)

Family. LARIDÆ.
Genus. *Sterna.*

S. hirundo - Common Tern - Indigenous - occasional
(Severn. Has been shot at Rownham Ferry.

S. arctica - Arctic Tern - Indigenous - rare
(Portishead.)

S. nigra - Black Tern - Summer visitor - rare
(Avonmouth. Rev. M. R.

Genus. *Larus.*

Larus minutus - Little Gull - occasional visitor - very rare
(One shot at Portishead, 1850.)

L. rudibundus - Black-headed Gull - Indigenous - not common
(Severn. Rownham Ferry.)

L. trydactylus - Kittiwake - Indigenous : occasional
(Avon and Severn.)

L. canus - Common Gull - Indigenous - Common
(Avon and Severn.)

L. fuscus - Lesser Black-backed Gull - Indigenous - occasional
(Avon and Severn.

L. argentatus - Herring Gull - Indigenous - frequent
(Avon and Severn.)

L. marinus - Great Black-backed Gull - Indigenous - occasional
(Portishead; Avonmouth.)

Genus. *Lestris.*

L. Richardsonii - Richardson's Skua - Winter visitor - very rare
(Once shot at Clevedon. Rev. M. R.)

Genus. *Thalassidroma.*

T. pelagica - Storm Petrel - Indigenous - rare
(Portishead.)

On the Age of the Cannington Park Limestone, and its relation to the Coal Measures South of the Mendips.

BY E. B. TAWNEY, F.G.S., F.Z.S.

Read at the General Meeting, November 4th, 1875.

WE propose, in a few words, to consider the age of the Cannington Limestone, as it seems to us to have much connection with the question of the probability of finding coal south of the Mendips—at any rate, south of the western part of the chain.

The question of finding Coal under the Thames' Valley was ably put forth by Mr. Godwin Austen, F.R.S., in 1856 (Q.J.G.S. xii, pp. 38-73) and the relations of the Mendip axis, with its supposed accompanying Coal Measures, to the secondary rocks was touched upon. It was more fully entered upon in the Report of the Coal Commission, being noticed by Prof. Prestwich (loc.cit. 47 and 163—165) in his contribution to the volume, and his views are summarised in the main Report (p. xii).

Messrs. Bristow and Woodward * of H.M. Geological Survey, in a communication to the "Geological Magazine" (vol. viii, 1871) have also discussed the question and mentioned the Cannington Limestone therewith. They consider this limestone of Carboniferous age, their words being "at Cannington Park we have the Mountain Limestone presenting its ordinary features, as they are so well displayed in the corresponding beds at Clifton, on the Mendip Hills, and in S. Wales," (loc. cit. p. 504). They argue from this fact both the probable existence therefore of a trough of coal measures between here and the Mendips, and that there "is no reason to suppose a great change in the Carboniferous strata immediately south of the Mendips." The reason of this last remark,—to use their own words—being the following: "the opinion has been expressed by Prof. Prestwich and Mr. Etheridge that, possibly to the south of the Mendips the Coal Measures might assume the Devonian type of Coal Measures."—The fear expressed by the latter authors being that they might be therefore worthless, as it is well known that the Devonshire Culm contains no series of workable Coals. As far as Mr. Etheridge is concerned, this opinion is in accordance with his views elsewhere expressed, that the Limestone of Cannington Park is of Devonian age.

We hence have two opposite views to deal with, one that the Limestone is Devonian and that it might be probably succeeded by Culm beds rather than productive Coal Measures; the other, that of Messrs. Bristow and Woodward, that the Cannington Park Limestone is Carboniferous, and that there is, therefore, no reason to suppose the Coal Measures, if present, to be of another type than north of the Mendips.

Certainly we agree with the latter, but the only reason they give for the determination of the Carboniferous age, is that of general lithological resemblance, which is, perhaps, hardly sufficient in the face of much divided opinion.

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* See also Quarterly Journal of Science, 1873, vol. III, N.S., p. 108.

It will be well therefore to review shortly the facts which have been accumulated by various workers, bearing on this question, and so incidentally sketch roughly the history of opinion relating thereto.

Leonard Horner in his "Sketch of the Geology of the S. Western part of Somersetshire" published in 1816 (Trans. Geol. Soc., 1st. series, vol. III, p. 365), considered the Limestone of transition (Devonian) age—his words are as follows.

"In the eastern part of the district, near the banks of the Parret, below Bridgwater, there is a nearly insulated hill called Cannington Park, totally different in structure from any other part of the country described in this paper. On the north side it rises directly from the marsh land, with a gradual slope to the height of 232 feet above the plain: on the south side it is not altogether cut off from the lateral branches of the Quantock hills. It is composed of a highly crystalline Limestone of a pearly grey colour, having a very close grain, and when struck, giving a ringing sound like that of glass. I examined it with very great care in order to discover whether it contained any organic remains, and particularly at the decomposed surfaces, and in those places where the stone was bruised by the blow of hammer, which generally detects any madrepores that exist in a limestone, but I could not find the slightest trace; and some of the quarriers who had worked there for several years, told me that they had never found anything of the kind. It contains, here and there, contemporaneous veins of a very pure white and opaque calcareous spar, and the strata are traversed by large veins of calcareous spar. In the latter veins the spar is distinctly crystallised, and in layers parallel to the sides of the vein, a circumstance which points out a marked difference between them and the veins of contemporaneous formation. On the north side of the hill there is a vein of red sulphate of Barytes about 3 feet thick in the widest part. This substance is not contiguous to the limestone, but is accompanied on each side by a reddish brown ochreous earth. Nor does the vein itself appear to intersect the limestone but to be interposed between two vertical masses. The barytes contains copper pyrites and green oxide of copper, and in the limestone near the vein I found quartz crystals scattered through the mass, giving it an appearance like a porphyry. I also observed in some places carbonate of copper in the limestone. In going over the top of the hill, which is very much covered by vegetation, the ends of the strata appear above the grass in many places in a vertical position and running between N.E. and S.W.; but on coming to the quarries where the rock is extensively exposed, I found that through it is evidently stratified, it is so shattered and crossed by rents in every direction, that it was impossible for me to discover what were the true planes of stratification, the internal structure of the stone affording no indication. Judging, however, from the more general direction of the masses, I think they may be said to be either for the most part vertical or at least very highly inclined and running between N. and S. I did not discover the least appearance of slate, or any circumstance that could connect this limestone with the subordinate beds in the graywacke series of the neighbouring hills, except its proximity to them. It more nearly resembles the Plymouth limestone than any other I am acquainted with; and although that has been found to contain both madrepores and shells, there are great portions of it where no traces of organised bodies can be discovered. It is also very probable, that by a more minute examination, they may be found in the limestone of Cannington Park, for it has, certainly, very much the appearance of what is called a transition limestone. and there are laminœ of calcareous spar dispersed through it which are strong indications of organic remains. It produces a very pure white lime, which is carried to a great distance."

The Rev. D. Williams mentions it in a paper read before the British Association in 1837. In the section given in the Report of that meeting (vol. vi, p. 95), the Cannington limestone is placed below the Foreland sandstone, at the base of the Devonian rocks: this paper was written "to determine the relative age and order of the Culm-field and its floriferous shales and sandstones."

In a paper on "as much of the Transition or Grauwacke system as is exposed in the counties of Somerset, Devon & Cornwall, (Proc. Geol. Soc. III., p. 115 & 158 ;) again similar views are expressed. Subsequently this author seems to have considered it of the same age as the limestones of the Quantocks, *i.e.*, M. Devonian,--see his manuscript observations quoted by Mr. Baker, (Som. Arch. N. H. Soc. Proc. for 1852, p. 129.)

The late Professor Phillips discussing the palæontological relations of the Devon & Somersetshire rocks, in the work published by the Geological Survey in 1841, (Palœozoic Fossils p. 142-3,) places this limestone in the Ilfracombe group; the fossils determined by him were *Cyathophyllum Damnoniense* and *Ceriopora similis*, the former a Devonian coral, the latter both Devonian and Carboniferous. I am not aware that this Devonian coral has been found subsequently, and it would be desirable to have some confirmation of its occurrence. Sir H. De la Beche considered the limestone to belong to the Devonian system of the Quantocks and in the older editions of the Geological Survey map, it was accordingly coloured as Devonian and taken as of the same age as the adjacent Limestones of the Quantocks.

In 1851 the late Mr. Baker, of Bridgwater, writing on the Geology of Somerset, (Som. Arch. Soc. I, p. 129,) notices the occurrence of encrinites and corals in it, while in a second article in 1853,* he boldly abandons views taken by the Geological Survey and previous authorities, and advocates its Carboniferous age. He here announces the discovery fossils which would point to this conclusion: these were *Conocardium*, *Productus*, *Orthis*, *Terebratula* and Corals; he considers these to agree with fossils in the Mountain Limestone of the Mendips. It is a pity however that their specific names are not given. He notices the "Oolitic structure and general resemblance of the stones," (*l. c.*, p. 129,) to the Mendip Limestone. The fragments of Encrinites are so abundant that they have been noticed by all observers.

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* "The Cannington Park Limestone," Som. Arch. N. H. Soc. Proc. III., p. 125-131, for 1852.

Mr. T. H. Payne also places it in the Mountain Limestone series (Som. Arch. Soc. Proc. for 1854, p. 105;) writing on the "Geology of the Quantocks," he remarks that it is very different to any limestone observed in these hills.

Mr. Etheridge's views are expressed in a contribution "on the physical structure of West Somerset and N. Devon and on the palæontological value of the Devonian fossils." Q. J. G. S., (1867,) xxiii., p. 568—698. As Palæontologist to the Geological Survey, he was asked by the Director to undertake a review of the Devonian Rocks, in connection with the claims of some geologists that these should be merged into the Carboniferous system. We may therefore conclude it contains his ultimate opinion and this is that the limestone is a Devonian outlier.

A section is given which represents the Cannington limestone included in the mass of Devonian rocks of the Quantocks, part of which crop out close by in the village of Cannington. There are no reasons given why the limestone is considered Devonian, and no fossil evidence is adduced. The adjoining limestones of the Quantocks yielded to the survey Palæontologist characteristic Devonian corals, but their absence here is passed over.

Sir H. De la Beche had most cautiously remarked of this limestone (Report on Devon and Cornwall, p. 55,) "that the connection with the rocks of the Quantocks cannot be traced satisfactorily. At Cannington itself, on the S. of the limestone, the lamination of the slate has a southern dip, and if this should coincide with that of the true beds, the slate would appear to rest upon the limestone, *unless* some great fault should occur." In the face of considerable difference of opinion Mr. Etheridge seems to have been rather unfortunate in the way he has touched upon this question.

The most valuable contribution on the age of the Cannington Park Limestone, is that by Mr. S. G. Perceval, of Henbury, (Geol. Mag. ix., p. 94, 1872.) He has here determined the Corals, which had been presented by Mr. Baker to the Taunton Museum: they are as follows:—*Lithostrotion Martini, irregulare, aranea Clisiophyllum turbinatum, Syringopora ramulosa.* He adds "The

Limestone in parts is oolitic in structure, and is identical in character with that developed in the neighbourhood of Bristol. It undoubtedly belongs to the Upper Carboniferous Limestone." With this conclusion we certainly agree and as the determinations may be relied on, it almost renders any further discussion unnecessary.

From our own cursory observation of the limestone we have obtained *in situ* an undoubted specimen of Lithostrotion irregulare, which is quite conclusive as to the age; several specimens of solitary corals were seen in the rock, poorly preserved, and which we could not identify specially. Of shells we found several crushed specimens, perhaps *Terebratula hastata* or possibly an *Athyris*, also a small *Producta elegans* or young *P. punctata.*

We are indebted to our companion, the Rev. H. Winwood, for an example of what looks like *Atrypa reticularis*, but we are unable to say whether it be really such; also for a portion of stem of *Actinocrinus.*

We follow Messrs. Bristow, Woodward and Perceval in recognising a lithological resemblance to the Carboniferous Limestone of the Mendips both in colour, structure, mode of weathering, jointing, &c., it mainly resembles the Carboniferous Limestone.

The joints are numerous and persistent; the main joints have a N. & S. direction. In the large quarry, at the S. E. end of the hill, and indeed generally the dip is rather obscure. At one end of the quarry, where we found the corals, the dip is plainly to the S. W., at an angle of about 30°, but at the other side of the same quarry the beds seem to arch over and the quarrymen pointed out to us that near the floor in this part they dip steeply in the opposite direction. The mass is therefore part of a dome or fold.

The limestone is intersected by many strings and veins of Triassic age; some filled by a red breccia bounded by a lining of white calc-spar; the Trias breccia of the veins contains pieces of limestone, the whole most firmly cemented together. These veins contain red sulphate of Barium, (the Barytes was noticed by

Leonard Horner,) and specks of green Carbonate of Copper, in fact the Barytes may be seen abundantly placed as an ornamental spar on the tops of walls round houses.

We may take it then as proved that the limestone is Carboniferous. It follows at once that it is totally disconnected with the Quantock series, seen a few hundred yards off, and its isolated position becomes one of great interest

The Fault spoken of by Sir H. De la Beche must certainly exist; what the nature of the dislocations are we may remain ignorant of for some time, but it seems certain that the Carboniferous Limestone must exist as a roll, or anticlinal, (of which Cannington Park is a small portion,) which probably holds for some way eastward under the Somersetshire marshes; certain it is that this is the most southern exposure of the Mendip Limestone, and hence N. of it under the Somersetshire Flats, we most probably have the productive beds of the Coal Measures, or part of them. It seems likely too, that they are at no great depth, as the New Red, or Lias occupy the surface. A boring of 600 feet in the centre of the marshes might probably determine the question.

Hence therefore as Messrs. Bristow and Woodward have already said, our hopes of finding coal here are materially strenghtened when once we have put aside the notion of the Cannington Limestone being of Devonian age, and have recognised the Carboniferous character as proved by fossils.

Insect Anatomy.

BY DR. H. FRIPP.

Read at the General Meeting, March 2nd, 1876.

ALTHOUGH it cannot be supposed that every member of our Naturalists' Society should take as great an interest in descriptions of insect structure as might be felt by a student of anatomy or entomology, I would fain hope that the subject may still prove sufficiently attractive to be received with some degree of favour even by a general audience. Were any special plea needed in defence of insect anatomy, I might fairly urge that insects are of infinite service and profit to man, or that they force themselves on his attention by becoming at times a plague to him or that they exemplify the most curious life-habits, and present, in many instances, the most beautiful objects in nature; and I might add that an interest is quickly acquired in any subject by becoming better acquainted with it. Against all such arguments, however, the objection prevails that "we cannot all do everything;" and this applies more forcibly in our own busy age than in any preceding one. And where all are so busy that very few care to turn aside from their own pursuits, or from other pressing interests of the moment, it is vain to remark upon the tendency engendered by division of labour to similar division, (*i.e.*, narrowing of interest) in the respective objects of our study.

But in addressing a society of naturalists—whose meetings are professedly held for interchange of thought and work and whose vitality is best shown in the variety of research undertaken by its members—it seems to me more fitting to rely upon the interest we all take in each others work than to insist upon the special importance of the subjects which we investigate. There is a community of interest in the commonwealth of science, as well as in the republic of letters, in which all students are privileged to share and to which all may appeal. One may plant the seed, another may water it, and again others may carefully tend its growth, until in due time and season fruit is matured which will be gathered by all who hold knowledge in honour, with a sense of enjoyment enhanced by variety of choice as well as flavour. And those will enjoy in highest degree who are themselves labourers in the garden of nature, and who, in contemplating the work accomplished by their associates, find relief from the strain of their own labours, and a genial spur to their scientific zeal when perhaps most needed.

What I have to bring before the Society consists of anatomical details of a somewhat technical nature, which I cannot pretend to introduce with any flourish of trumpets, and which I shall not attempt to embellish with glowing descriptions of the marvels of insect life, or by anecdotes of curious habits, which may be found in abundance in all our books. It is rather my aim to direct attention to the less cultivated but more practical field of research which here lies open to the naturalist, a field peculiarly his own, full of promise and, though demanding some exercise of skill and patience, worthy of his best energies. And it is my hope that some of our members may be induced to take up a study which will interest them more and more as they advance, and which will yield valuable materials for our evening discussions.

I have fixed on a particular example of insect anatomy for several reasons. In the first place, I believe that precise knowledge of insect structure, derived from a given source, is of greater value than vague statements gathered from the general surface of insect history; and secondly, because I have not met with any detailed account of the anatomy of the cricket in our science journals, although the creature is familiar to us as household words. Another reason for my selection was, that the insect is always to be got, so that any spare time could be given to its examination, without fear of being forced to leave the work incomplete for want of material. For the same reason, also, anyone can obtain and examine it for himself, and so be in a position to criticise and correct my results.

In this communication I limit myself to the descriptive anatomy of a single insect because the lessons to be learnt from each example—whatever be the one selected—are best learnt by an exhaustive study of it, no part or detail being omitted on the supposition of its being already known. Facts freshly observed, and communicated direct by the observer, impress more, and come with more interest than statements compiled from works already known. Even if not new, they have, for the time and purpose, the freshness of re-discovery, and a lasting value if they settle what was not definitively accepted. Nor is the time spent in such examinations disproportionate to the results gained. For the anatomy of a single insect not only illustrates that of all its kind but also affords a vantage-ground from which we get an insight into the general nature of insect organisms, and recognise variations and contrasts as well as likeness of structure, so that time is saved in all subsequent investigations. Each onward step gives us possession of new standards of comparison whereby to interpret structural peculiarities, and additions or omissions of parts and organs and lastly, any one item in the long series of facts may throw unexpected light upon phases of development, and so help to widen the basis upon which higher generalisations may be founded.

What has hitherto been accomplished in insect anatomy has been of great service in furthering the purposes of the entomologist, as well as of the comparative physiologist. It is so obvious as scarcely to need remark, that classifications once based on external appearances and unscientific fancies have undergone frequent remoulding upon the more precise indications of anatomical structure, and have improved in proportion as our knowledge of the relation between insect-life habits and their external and internal organisation becomes more accurate. It was not, for instance, until Cuvier demonstrated the broad distinctions in the organs of vegetable life, that the incongruous animals once associated under the heading "Insecta" were arranged in their respective divisions of Crustacea, Arachnida, Myriapoda, and Insecta, now defined by striking contrasts of circulating and respiratory apparatus by different number and arrangement of body segments, limbs, &c. &c., and by distinctive characters of sensory and nerve organs.

But in the classification of insects, properly so-called, physiological anatomy has been less happily applied. The division of insects into groups, according to external signs of metamorphosis does not correspond with any principle of natural affinities between the members of the order so constituted.

Metamorphosis as a basis of classification necessarily fails when the visible changes differ so greatly in degree amongst animals nearest in affinity. And, moreover, its real significance as an indication of the process of evolution through which all creatures pass was so imperfectly recognised by those who first employed insect metamorphosis as a means of classification, that two of the three divisions were founded on a more or less absolute *negation* of metamorphic phenomena. So far as the unequal prominence of visible metamorphic changes may assist the entomologist in distinguishing his orders, it might be accepted for what it is worth: But the true anatomical expression of metamorphosis points rather to resemblances than differences to homologies than analogies to homogeneity of structure rather than heterogeneity. For as in its physiological aspect, metamorphosis reveals an underlying unity of action throughout the whole animal kingdom, so from its anatomical analysis we discover unity of structural elements, and their modes of evolution—the differentiations which ultimately ensue being the result of special individual conditions. In short, metamorphosis belongs to a more recondite chapter of biology as a portion of the higher generalisations of developmental law; and though it affords truly wonderful and instructive glimpses into insect evolution, is misapplied in the limited uses of classification.

But other classifications founded with more success on permanent external features demonstrate the value of insect anatomy. In particular, the anatomy of the mouth and accessory appliances has proved of great importance. For its masticatory or suctorial character has a definite relation to the insect's nutritive organs, its food and life habits. Then, as secondary characters the presence or absence of wings with their number and arrangement, together with difference of antennæ, limbs and feet, offer many distinctions which have a direct connection with the modes of life of each species so characterised. In all classifications the various life habits afford natural and simple means of characterising insects, obviously, because it is more easy to observe these than to determine the anatomical peculiarities with which they are associated.

It is, therefore, not surprising that the nervous system plays so little part in any scheme of insect classification. The homogangliate character assigned to insects, in common with other divisions of articulata, admits indeed of considerable variation; but the infinite diversity of external characters of the insect's body is not accompanied by such obvious differentiations of nerve organs as would serve for purposes of classification. It cannot be doubted, however, that all the powers and faculties of insects expressed in their life habits, stand in close connection with the degree in which cephalic thoracic or abdominal ganglia are developed. From the relation, size, and complicity of the nerves and Ganglia of these three divisions and of the sensory organs, the probable conditions of the insect's existence may be fairly premised and the particular phase of metamorphosis of some, probably of all, (if we were sufficiently acquainted with their nerve anatomy), may be at once declared from the corresponding condition of dorsal chord, as I shall have occasion to shew in the sequel of this paper.

Thus it appears that insect classification has improved, so far as proper use of structural indications has been made. But classification is itself only a *means*, not an *end*, and insect anatomy has an important bearing on many other questions than those which occupy the Entomologist. I propose, therefore, to devote a few minutes to the consideration of those physiological aspects of insect life, which offer most promise of interest, and justify that closer scrutiny of structural details to which I have invited attention.

It is seldom that popular enquiry and anatomical investigation run together. But, if at any time, or upon any question, it is when the mysteries of organic life and animal automatism become subjects of speculation.

On the popular side, insect life has always suggested a belief in some form of "*soul-life*" as our German friends would term it. On the scientific side, insect-nerve physiology has yielded important experience, and thrown great light on the specific functions of nerve and ganglionic centre.

In the several orders of Articulata, we see the machinery of automatic action in its simplest and most complex forms, free from many complications which render the phenomena in animals of higher cerebral organisation more obscure. In the insect, the study of reflex action rises in significance proportionately with the perfections of special sensory functions, and of those actions, called "instinctive," which govern the whole organism. And the constructive type of the instruments by which all these functions are performed is especially suggestive, while the field of psychologic debate is greatly narrowed by observing the peculiar association and co-ordination of the several insect organs and faculties. In former times the minds of philosophers were much exercised in discussing the limits of volition and the antagonism betweem instinctive and rational acts. But as soon as reflex action was discovered, or rather explained, and its observed occurrence in the higher animals and man himself made us familiar with unconscious automatism, the inferior creature was at once dispossessed of its supposed right to a "soul-life." At the present moment, the continually extended observation of automatism, which seems to keep pace in its sphere of action with every added cerebral function, has led to its being accepted by many as the *end* as well as the *beginning* of our sentient existence. And if consciousness, *i.e.* the perception of our own sensations, acts, and thoughts, be also the outcome of organic action, the mental calibre of man himself, no longer postulated by metaphysicians, becomes a question of how many missing links there may be between man and his *congeners*.

But while the philosophers have "moved on," the old belief, that insects possess the volitional powers now almost denied to man, remains with those who have not followed modern movement, and even our boasted civilisation is often unfavorably compared with the insect's social instincts. Its extraordinarily diversified life-habits—solitary or gregarious, predatory or timorous, parasitic or social; upholding regularly constituted polities, monarchical or republican; and, for all we know, as polemically inclined as man himself—*seem* to imply the causal relation of insect action to will, and more than simulate the subjection of motive to thought. One thing is however certain, namely, that the modern doctrine of acquired and newly-inherited faculties does not apply to the insect so as to make it grow wiser by experience, except in its own generation. Yet the world is ready to affirm that an insect reasons because its acts appear rational to man, whilst our advanced philosophers are occupied in reducing seemingly rational acts of man to involuntary acts of his body, of which he is unconscious.

Now, to this see-saw of opinion no end can be foreseen until the disputants are all equally informed, and provided with the same armoury of weapons; nor until the whole evidence of organic mechanism is collected and sifted to its last detail. No one meanwhile will play a more useful part in the collection of this evidence than he who succeeds in working out some unsettled problem of homology of structure, or in clearing up some intricacy of nerve physiology. Nor will the naturalist anywhere find examples of organic structure more suited to render the solution of physiological or mechanical problems clear to our perception than in the class Insecta.

But if such applications of anatomical science be thought too profound for leisure hours—if we care not to dive into the secret recesses, and fix our searching gaze upon the inner nature of living beings and their affections, there remains still an infinite fund of instruction in studying the lighter subjects of insect anatomy. The external changes which indicate the phenomena of metamorphosis can nowhere be seen so clearly, and in such relation of sequence, as in the insect. For, in the higher animals, these phenomena are concealed because the development to which they are related occurs in the earliest phases of life, whilst in the lower animals they are disconnected and lost to view by absolute separation of the individual into quotient parts, which have a separate life in time, place, and space. But in insect metamorphosis, the anatomical changes are more striking because we can observe their sequence, and follow the different phases of existence as the organism is adapted for life in earth, air, or water. Nature here exposes her operations to the eye of the naturalist, and leaves her experiments ready to his hands, on his excursions, or at home, in his garden, his home, and even his fireside.

But apart from the marvellous changes of structure relating to metamorphosis of insects, the actual condition of each individual, whether in young or old, or any intermediate phases of its organism, presents such a variety of problems of mechanical construction in the adaptation of its bodily organs to the habits and external surroundings of its life, as must interest any person even but slightly acquainted with insect anatomy. The dermo-skeleton of Articulata in general, with its various forms of leverage, jointing, and modes of obtaining strength at one point, flexibility at another, rigidity at a third, expansion of surface with least expenditure of material and greatest saving of weight or bulk, is sufficiently striking in all, but in none so remarkable as in the insect division, whose wings, feet, antennæ, probosces, palpi, eyes, &c., have always excited attention and admiration. The transformations of this dermo-skeleton—now soft and silky, now encasing head, body, and limbs, in a panoply of armour, with heavily-jointed limbs and weapons of offence and defence; now thinning into diaphanous skin and gossamer wing, bespangled with scales of exquisite beauty, whose markings send microscopists into transports of enthusiasm (and perplexity!) or covered with irridescent hairs, spines, thorns, and prickles of woful itching power, or emitting, to the dismay of the collector, strange odours and irritant juices from glands beneath, or again, armed with borers, grinders, pincers, saws, rasps, stings and lancets worked with an intensity of power which, if exerted by an animal of larger size and proportional muscular energy, would appal a Titan—in short a dermo-skeleton which illustrates so complete a repertory of mechanical contrivance, and enables the insect to perform in miniature all that bird, beast, and reptile can do, is a sufficient task for the most laborious student.

But in addition to this external, we find an internal anatomy of equal complicity, indicating in its highly specialised organs the capacity of an insect to conform to every circumstance and influence of its external surroundings.

It is worthy of remark that the class Insecta is not a mere connecting link in the chain of animal creation, but a kingdom whose members inhabiting earth, air, and water, illustrate the doctrine of adaptation under the most extreme conditions more completely than any other class. And whilst repeating the characteristics of other classes, and presenting various analogies with animals both above and below them, possess, in addition, individual and special characters of their own, and so special a place amongst the great divisions of the Invertebrata as to stand indisputably at their head. But, just as our ideas of life in its most elementary form are best exemplified in the least organised matter, so the most striking additions to, and extensions of this elementary life might be expected to be seen in organisms, in which the primary phenomena of living matter undergo the greatest changes and transformations under the physiological rule of adaptation to external influences. This is notably the case in insects, and must be so when we consider the extreme as well as middle ranges of insect life. And the result is seen not only in the variety of life-habit but also in speciality of organs, and even in special perfection of individual tissues. For instance, the muscular energy transcends anything known of other animals. Attached to the strong dermo-skeleton, it enables the insect to resist crushing weights or to lift and drag them, to burrow into wood, to crush stone and even metal, with contractile force that would not be credited but for repeated trustworthy observation. *Strength* is not however its only property, for *rapidity of contraction* is such that the flight of a dragon fly or even a common house fly cannot be equalled by bird or beast. And the compound effect of strength and rapidity of action is manifested in leaping powers which no other animal exhibits. Anatomy shews, in fact, that insect muscle is the most perfect of known muscle tissues. But, further, this expenditure of muscular power implies correlative power of nutrition and excretion. Anatomy shews that the peculiar respiratory system of the insect converts the whole creature into a lung, and at the same time into a drainage apparatus, the excreta being gaseous. With respect to nutrition, the replacement of used up force argues the necessity of rapid assimilation for the ordinary expenditure rather than of stored up material, but the fatty tissues of the insect are very remarkable as a store of oxidisable fuel in concentrated bulk. The possible capacity of nutrition is, however shewn during the periods preparatory to metamorphic changes, when the amount of food taken, and increase of weight, are unparalleled in the history of any other creature. In the *active* phases of insect life, circulation is also more complete and special than is commonly supposed; not only do all cavities and interstitial spaces between the organs serve as blood channels, but the nerve trunks and ganglia are enclosed in sheaths which I consider equivalent to blood vessels or lymphatics, through whose walls interchange of fluids takes place, besides which, many of the finely ramifying tracheæ are apparently enclosed in canals filled with the circulating fluid. Considering, indeed, the penetration of every tissue of the body by terminal membranous tracheæ and the rapidity of aeration and gaseous exchange, it seems difficult to understand why an insect hovering on the wing all day or darting through the air like a dragon fly should not dry up altogether, unless some provision existed for surrounding important organs with fluid. That the common belief in the physiological inferiority and anatomical imperfection of insect circulation is erroneous, further appears from the consideration of other changes involved in the "fast life," of our insect. And particularly from the conversion of the nutritious fluid into the remarkable series of products, secreted by the glandular organs which receive their supplies from circulating channels and lymphatic vessels.

Silk, honey, wax, cochineal, cantharidine, formic, and other acids, irritant fluids which excite disease in plants and animals, are all suggestive of the subtle chemistry of insect secretion which thus spreads good and evil upon the world around. The varieties of gland and other peculiar arrangements of insect structure by which such results are brought about, form therefore interesting points of anatomical enquiry.

There is yet another chapter of insect history, namely, *parasitic* life, which closely concerns us who suffer grievously from it, and which is mainly elucidated by anatomical investigation. In all these particulars the practical and scientific interests of mankind run together, whether in finding remedies for the plagues which *ignorance* of insect habits brings upon man, or in discovering the causes of ravages which devastate his crops, or in improving the management and increasing the productiveness of insects which yield him valuable materials. In relation with these practical issues stands the history of development and reproduction, which, so far as anatomical investigation has been prosecuted in this direction, reveals unsuspected facts, and leaves unexpected mysteries. The altered conditions and habits of the insect and its changed functions find equivalent expression in external "ecdysis," and internal "metamorphosis." But such revelations leave all unexplained mysteries more mysterious than before—such for example as the selection of place in which to deposit ova, immigration, and social instincts generally. Nor is the study of insect *sensation* without its general as well as scientific interest. Does the sense of pain or pleasure influence the movements of insects? Is there any consciousness of sensation or retention of past sensation in the form of memory? Do the special senses, the perfection and acuteness of which are undeniable, influence the insect's action through a common sensorium, or does each reign independently over those actions of the body to which they stand in special relation· These are questions, a competent discussion of which is only possible when the physiological anatomy of cerebral and sensory ganglia has been thoroughly determined. Finally there remains that faculty which presents itself to different minds in such different aspects that it would seem scarcely possible for all to agree in discriminating between instinct and reason.

If, in the foregoing remarks I may seem to have laid myself open to the charge of falling into the vague generalities which I professed at the outset to avoid, I must ask you to bear in mind that I am not setting up any defence of Entomology as a study, but that what I have to say of the anatomy of the cricket necessarily bears on the general characteristics of insect structure, and that any question of physiological interest, arising naturally out of anatomical premisses, falls within the scope of my paper. A preliminary glance over the whole subject is therefore useful in indicating the precise facts which deserve special notice, and also the precise relation in which each fact stands to the general physiology of insect life.

I conclude these introductory remarks with a few words on the dissection and preparation of the soft parts of insects.

Much of our knowledge of internal structure has been gained by observation, under the microscope, of insects possessing a transparent integument. The larval forms are most suited for such examinations, and are best examined whilst living, when circulation or muscular action is to be studied. If the parts to be studied do not require hardening, it is best to dissect them out immediately after death, glycerine being used to keep them transparent, for when preserved in glycerine the structures can be left to any convenient time for examination. When spirit is used, hardening occurs in a few days, after which the tissues shrink and become granulated and knotted together so as to break under dissecting needles; besides which they gradually get stained and opaque, so that they are not any longer well seen under the microscope by transmitted light. Water should not be used when dissecting, but the object must be floated in glycerine, and all fatty tissues removed as soon as possible.

The magnifying power under which dissection is carried on necessarily varies with the minuteness of the object—the lowest power under which the parts can be distinguished should always be chosen, because they can be kept better in sight and a firmer control over the movement of the dissecting needles exercised. With high power, the object escapes readily out of the field, and the needles are not easily brought to bear upon it. The power should be either a single lens, or a combination of lenses which magnifies without inverting the image.

Most insect preparations can be examined and made under a low power (5 to 25), but it is well to examine them under higher power during their preparation (50 to 75). When histologic elements are studied, still higher powers are needed. If, for instance, insect muscle is the object to be examined, the striation may be readily seen with quite low powers, but the arrangement of sarcous elements can be demonstrated only when powers varying from 400 to 800 are used. And by far the most beautiful objects are obtained when polarised light is used and advantage taken of the different refracting power of the discs and intervening substance. The ordinary striation of muscle fibre may be seen most perfectly in the muscles of the Thorax which naturally split up into long fibres, offering excellent specimens for study, (*e.g.* in the common house fly). For minute analysis of the sarcous mass, the muscles of mites (Trombidium) have been recommended, as the striation of such muscles is remarkably coarse and distinct.

Muscle must be taken from an insect immediately it is killed. It may sometimes be advantageously treated with alcohol, or osmic acid (weak solution) and prepared in glycerine. When studying the phenomena of contraction, which will be seen in various phases along the length of the fibre, the muscle should be examined either in living insects, or in recently removed parts immersed in blood serum or some albuminous fluid (white of egg *e.g.*), or in glycerine, but never in water. In insect muscle preserved in spirit, especially if the insect has been dropped, while living, into the spirit, the varying state of contraction of different elements of the same fibre may be seen just as fixed at the time of death.

It frequently happens that the anatomist has not the opportunity of dealing with insects in the living or fresh condition. In such cases the specimen must be preserved in weak alcohol.

In the dissection of insects, different methods of treatment and manipulation must be adopted, according as it is desired to learn the structure of any particular organ, or to prepare and mount specimens, and economise so as to get the greatest number of preparations from a single insect. In learning the anatomy of any insect, not previously studied, a few specimens must be sacrificed by cutting and picking to pieces. But material may be saved by following same methodical plan. *External* parts can of course be studied as they present themselves, but it is worth while to preserve the dermo-skeleton, either whole, or in parts (sections), and this is best accomplished by boiling in solution of potash, then washing in cold water and removing with scalpel or brush any remaining soft parts (ligaments, membranes, tracheæ, &c.). To mount them, a suitable fluid, spirit, turpentine, balsam, glycerine, &c., must be used, and a convenient size and shape of cell chosen. The parts composing the mouth require special attention and should be separately mounted. The whole head may be divided in various directions, yielding longitudinal, transverse, and horizontal sections, each displaying some particular aspect. For example, a longitudinal section shews external and internal lateral views of the cranium with eye, antennal first joint (the antenna being cut off) mandible, maxilla, and palpi. Cross sections yield anterior and posterior views of the internal processes, separating the cranial and facial halves. Horizontal sections shew external and internal aspects of the vertex of the cranium with orbital and antennal sockets, labrum, &c., or of base of cranium with maxilla and palpi, gula, labrum, lingula, paraglossœ, &c. The study of such sections of the dermo-skeleton, from which the soft parts are removed by boiling in solution of potash, is a necessary preliminary to the study of the very intricate anatomy of the soft parts contained within them, *e.g.*, Tongue, pharynx, æsophagus with its salivary glands and muscles, supra and infra-æsophageal ganglia and nerves, together with a mass of intra-cranial muscles arising from the inner surface of the cranium and internal processes, and attached to æsophagus, palate, and mandibles.

The student will be greatly assisted, and valuable time saved, by purchasing all good insect preparations which he can obtain commercially. Such preparations will probably be far better made and mounted than those which he makes for himself. But no cabinet of preparations will teach that knowledge of insect anatomy, which is to be gained only from actual dissection. The relation of the soft parts to the dermo-skeleton, and their own relative position to each other, can only be learnt in their entirety by those who dissect them in the fresh state and examine them *in situ.* Besides which, preparations of the most important and interesting parts are not usually made for sale, as they are difficult to dissect, and demand much time in preparing. But whilst dissecting for himself, the student will find every tissue and fragment of tissue well worthy of study from histiologic points of view, as well as on account of their anatomical relations. For instance, it is always well to examine fragments of muscle fibre scattered in the field, for the chance of securing good examples of nerve insertion under the sheath of the muscle, and distribution of its terminal filaments in the muscle substance. Fragments of gland structure sometimes offer unexpected yet beautiful specimens for preparation. The same may happen with varieties of gland in mucous membrane of intestines and other organs (testis, urinary tubes, hepatic tubes, &c.). Beautiful varieties of fatty tissue and dermoid tissues or exquisitely striated muscle (as in the coats of the dorsal vessel) or curious forms of tracheal ramification and wonderful networks distributed over or penetrating through other tissues may be secured as chance prizes, if looked for amongst the debris after the principle organs have been secured.

The dissection and removal of the soft organs and finer structure is however attended with considerable difficulty when enclosed in a casing of such tough and resistent chitin integument as forms the dermo-skeleton of Coleoptera, Orthoptera, Hymenoptera and other classes. Of course this difficulty is greatest at the natural cinctures which mark the chief divisions of the insect into head, thorax and abdomen, and wherever internal processes connect the anterior and posterior surfaces, as happens for instance in the case of the cricket, both in the head and the thorax. The abdominal organs are easily removed from almost every kind of insect, but their continuity with the parts contained in the thorax can be preserved only by skilful manipulation. As the alimentary canal, and nerve chord, extend from head to tail, the integument must be slit up from end to end on the ventral side, but not directly in the median line, because it is best to remove the ganglionic chord with the æsophagus and intestine. In the instance of the cricket however the intra-cranial portion of the æsophagus, with its closely adherant infra—and supra-œsophageal ganglia, cannot be detached without first cutting off the head and very careful tearing out, as these organs rest upon a saddle-shaped osseous plate in the very centre of the cranial cavity. The ganglionic chord within the thorax is also enclosed between forks of internal osseous plates, but by following it up from the abdomen where it lies free, it can with a little care be got out entire. It is best to keep the whole insect floating in glycerine, the body being secured in any convenient way in a fluid-holding cell of suitable form.

To exhibit continuous systems of organs, and show their relative position to the several divisions of the external integument, longitudinal and transverse sections are useful. But these cannot be well made without a preparatory hardening process. If complete sections of the whole body are desired, the hardening process should be supplemented by soaking the parts in some material which will preserve them in unchanged position under the action of the knife. The following plan which has been found most successful in making sections of diseased structures, and is employed by Professor Ranvier appears to me the most suitable for the purpose.

Place the parts (or the whole insect taking care to make such punctures or slits in the integuments as will allow the fluids used to penetrate thoroughly,) in alcohol for 24 hours, a time sufficient to to fix, without contracting the tissues. Then, in solution of picric acid for a few days, by which the spirit is expelled and the parts are again slightly hardened. After a few days wash in pure water and plunge the preparation into a weak solution of gum arabic which completely penetrates the tissues in a few days. Then remove and place in alcohol, which takes up the water, and the gum solidifies and yields a mass which resists uniformly the cutting blade—microtome, or razor—according to convenience. When the section is made, the gum dissolves out after soaking a little while in water, and the preparation can be floated in the fluid selected for preserving it. Cells are of course needed for preparations of larger parts and organs.

In the cricket's head, to which our attention is now directed, the same sections which were shown in preparations and drawings, displaying the dermo-skeleton, are equally serviceable in indicating the position of the soft parts. It will be seen from the drawings that this cranial dermo-skeleton contains within it a large number of organs which are facial rather than cerebral. The longitudinal vertical section in median line, shows the oral cavity, roofed by a long line of palate with the large and fleshy tongue beneath. At the isthmus of the jaws, suspended by muscles from the vertex of the cranium, the oral cavity becomes continuous with the œsophagus, situate high up, and resting on the central saddle formed by the union of four internal osseous processes, two of which descend from the vertex (one on each side,) whilst the remaining two rise from the base of the skull. From this central position the œsophagus, with its bunch of salivary glands, passes down between the two lower processes, into the neck. Nearly the whole of the intra-cranial cavity is occupied by the muscles which arise from its internal surface and pass forward to the mandibles. The only really cerebral organs are the ganglion masses of the supra-œsophageal ganglion, which correspond with the *corpora quadrigemina* of the vertebrate brain, and the ganglia of sympathetic and vagus nerves. The vertical cross section, which the drawings represent as made immediately through the vertex of the head, shows the internal processes already mentioned, and, as seen in this section, they show how the cranial cavity is partitioned off, leaving special chambers (orbital, antennal) on each side, whilst in the longitudinal section the separation of cranial cavity from the face is seen to be effected by the same processes.

The central slice, obtained by a vertical cross section of the head, commencing from the top in front of the antennæ and carried down to the throat, and another parallel section made behind the antennæ and slicing with it the anterior portion of the cornea on each side, is a most important section. This central slice (about $\frac{1}{12}$ to $\frac{1}{16}$ in. thick) contains the whole brain with sympathetic and vagus ganglia, together with æsophagus and its salivary glands. Next in importance are horizontal sections from the occiput to the top of the nose. Looking towards the base, we see, as in the drawings and preparations, the symmetrical disposition of muscles, running on each side from the inner surface of the cranial cavity to the mandibles and maxillæ, with the central position of the æsophagus and the infra-æsophageal ganglion in front of it, also the tongue and the muscles connecting it with the anterior edges of the ascending internal processes, and the maxillary muscles on each side, with the maxillæ and all the parts of the lower jaw. And looking upon the surface of the section of the upper half of the cranium we see, as in the drawing, the symmetrical disposition of the orbital and antennal chambers and the optic ganglia on each side, the vault of the fauces and palate, and the inner surface of the labrum, &c.

As the descriptive anatomy of the head of the cricket will occupy a whole evening, the present rough sketch is intended merely to describe in a general way, the drawings before us, and so to enable those who examine the preparations on the table to understand to what parts they belong. By examining the principal sections with a low power, a general map of the most important organs, and their actual and relative position, appears spread out before the observer. By a series of slices a corresponding map of each organ or parts of organs is obtained, and by piecing together the parts contained in each slice in their original order, the continuity and contiguity of the several structures is made out. In this way the drawings have been made which are now exhibited, and the result exemplifies the use of this method of obtaining exact figures, illustrative, first, of regional and ultimately of systemic anatomy. The details with which the general outlines are filled up, have been drawn from other series of preparations and dissections of parts obtained by varying the sections. The number and complicity of organs, and the minute details of structure, may surprise many who have not before considered the subject of insect anatomy, and their beauty and delicacy will, I hope, prove sufficiently attractive to counteract the tedium of listening to the descriptions which I have yet to offer.

(To be continued.)

NOTE.—As it has not been found practicable to reduce the diagrams, or to make fresh drawing from which illustrations to accompany the text could be produced in time for publication in this volume, the plates and descriptive text will follow in our next number.

On the Limits of the Optical Capacity of the Microscope.

BY PROFESSOR HELMHOLTZ, with a Preface by
DR. H. FRIPP.

THE last number of our Proceedings contained a translation of Professor Abbe's article on the "Theory of the Microscope," originally published in Schultze's Archives. In that article, Professor Abbe stated the general conclusions at which he had arrived after a prolonged investigation of the optical laws affecting the transmission of light through the lenses of the microscope. These laws relate to 1.—The divergence of the rays of light forming a geometrical image. 2.—The brightness of that image. 3.—The dispersion of colored rays, and its consequences, and 4.—The diffraction of light occasioned by minute particles in the *objects* placed under, (or before) the microscope. In explanation of these several phenomena, a theory of the microscope was stated in general terms, the mathematical demonstration of this theory, and its various applications, being reserved for a future communication.

Simultaneously with Professor Abbe's researches, a most interesting investigation of the same subject, was completed by Professor Helmholtz, and appeared in Poggendorff's Annals (1874.)

The theoretical grounds taken by these two authors are identical, and their results, so far as the researches were directed to the same points also agree. But in each essay the mode of treatment is thoroughly independent, and the experimental proof of the conclusions respectively obtained is conducted by each writer in a separate and original method. The mathematical demonstrations omitted in Professor Abbe's article are fortunately supplied by Professor Helmholtz, and the two essays are confirmatory and supplementary to each other in several other respects, whilst in both we recognise that clearness of thought and precise knowledge of the subject treated, which justifies entire confidence in the conclusions. It seems therefore to me that Professor Helmholtz's essay should naturally follow in this number of our Proceedings. For, taken together, these two essays form the most complete and authoritative exposition of the optical principles involved in the action of microscope objectives, and the most trustworthy interpretation of that action, and consequently of the capacity of performance of such objectives, that have as yet been made public.

In introducing the first of these essays to the notice of our Society, I expressed my strong conviction of its high value as a contribution of really scientific character to the theory of the microscope. The essay of Professor Helmholtz deals somewhat more fully with that aspect of optical science which is known as physiological optics, and of which no physicist of our times has a more profound knowledge. This point of view had not been neglected by Dr. Abbe, but in my translation two short sections of his essay. which referred to brightness of image, and to certain enquiries connected with illumination of the image, were, for reasons mentioned in the preface, omitted. It is therefore so much the more satisfactory that Professor Helmholtz's essay enters fully into the subject. The peculiar conditions under which objects are seen when magnified by the microscope, can only be understood by studying both aspects, physical and physiological, in connection with each other. The laws of formation of optical images (when amplified by interposition of lenses,) and the laws of dispersion of the rays by which these images are formed, help us to an interpretation of the physical agencies at work, and shew us also why the extreme amplifications employed render vision through the microscope more imperfect than through any other optical instrument, such as telescope, or camera. But the analysis of these physical agencies and effects, involves the consideration of the eye itself, as an optical instrument through which the microscope image must pass to reach the perceiving organ. And apart from the imperfections arising from aberrations and dispersions of rays in the instrument, other imperfections of the retinal image will be found in considering the more or less favorable conditions under which the microscope image enters the eye. The area into which the microscope image is collected at the eye spot (over the ocular,) varies in size with the amplification, and is smaller in proportion as the amplification is greater. And this variation of size is accompanied by variation in brightness of image and distinctness of detail. If the area of illuminated image entering the pupil is smaller than that of the pupillary aperture, loss of brightness is felt. For the condition of most effective illumination (brightness of image) is that which obtains when the area of image at the eye spot, and the area of the pupil, are equal. On the other hand, a small and intensely bright spot of light in front of the pupil presents the exact condition under which entoptic shadows obscuring the image are thrown with it on the retina. But as brightness of image is as necessary to distinct vision as any mere amplification of detail can be, it follows that a suitable relation of "aperture" to "magnifying power" must be maintained in every good objective; for "aperture" in this particular case means the measure of light admitted with the image-forming rays; and as a larger measure of light is required in proportion to the increase of magnifying power, so it is only when these two factors are suitably proportioned that details in the objective will be rendered clearly visible in its microscope image. And again, as respects the bundle of rays collected into a smaller or larger area at their entrance to the pupil, the regulation of illumination from without is better maintained with a large "aperture" of objective by means of diaphragm openings and stops than by using stronger light with diminished aperture. Thus the management of illumination, and manipulation of the microscope to obtain good definition, though for the most part left to empirical practice, would be more easily and thoroughly acquired if the physiological laws were carefully studied. But another and far more serious deterioration of definition arises from excessive diminution of area of the image entering the pupil. This contracted area —the necessary consequence of the optical combinations used to obtain high amplification—has the same effect as any minute aperture through which a luminous object is viewed, and occasions, as is well known in physics, those diffractive effects which obscure the outlines of an image by making them overlap each other. On this fact is founded the whole argument of Professors Helmholtz and Abbe respecting the limits of microscopic vision, as well as the corollary which directly follows from it respecting the ultimate limits of minuteness to be assigned for vision of any and every kind of material atoms with the optical apparatus and materials yet employed. The theory of the microscope as interpreted by Helmholtz and Abbe on identical physical and physiological basis, is therefore of great importance in its general bearing in physical science, and the precise and comprehensive treatment of it in the following pages worthy of careful study.

As respects the translation now offered, it is only necessary to add that it was undertaken at the same time as that of Prof. Abbe's essay, and with exactly the same motives. Our readers will it is hoped bear in mind that the translator's object was simply to make known to those who could not otherwise so readily inform themselves, the views of scientific men abroad, whose authority on these subjects is at all events high in their own country, and whose teaching he had himself accepted with pleasure. No mention of English contemporary work was needed therefore in the brief introductory notice of Dr. Abbe's article. Since its publication, however, the translator has been questioned respecting English contributions to the theory of the microscope, and he therefore ventures to add a few words on this subject.

One may be well excused from referring to the meagre optical chapters in our handbooks on the microscope, which might perhaps suit the "Boys'-own-book," but which contain neither demonstration nor diagram of the course of rays through any sort of modern lens system, nor even a rough application of its very elementary statements respecting refraction and reflection to any special formulæ of constructions, according to which the lens combination of an objective would be worked, or by which its performance would be tested. Nor can the favorite descriptive chapter of the instruments of various makers help anyone to a theory of the microscope. The opinions expressed by experts and authorities on definition, penetration, resolution, aperture, &c., as being so many separate *powers* or qualities, besides savouring strongly of a mythological period in the history of the microscope, have only retarded the search in the right direction, viz., by physical analysis and physiological study of optical phenomena for true causes of the effects observed. And in fine it must be confessed that our handbooks fail greatly in respect to theories of the microscope, however valuable their information on practical and mechanical subjects, and more especially on all branches of science involving skilful *use* of the instrument.

In the absence of such handbooks as the German students possess, and of which the work of Nägeli and Schwendener might be cited with admiration as an example, the scattered articles and shorter notices in our serials rise into comparative importance. But it will scarcely be contended that such desultory and disconnected communications and such remarkable disputes respecting easily determined facts, should be accepted as an equivalent of the systematic theory and practical demonstration which distinguish foreign study of optics applied to the microscope, from our yet unlearnt, or at least unwritten, micrographic science.

Various communications bearing more or less on the optical capacity of lens-systems constructed on given formulæ or for employment as "dry" or "immersion" objectives, have appeared in the Monthly Microscopical Journal, the Quarterly Journal of

Microscopical Science, and the Transactions of the Royal Society during present and preceding years. Of these, one series of papers published by Dr. R. Pigott claims to be a mathematical exposition of optical laws governing the divergence and dispersion of rays of light transmitted through different kinds of glass. Another series of papers by Mr. Wenham takes the practical direction to which English microscopists mostly incline. The communications of Mr. Sorby have enriched microscopic science with the most ingenious and successful applications of spectrum analysis that any country can boast. To all these gentlemen the English student may feel equally indebted for their respective labours. And the mention of these in juxtaposition with the work of so great an authority as Prof. Helmholtz and so conscientious a workman as Prof. Abbe, is not only due as a recognition of the individual services, but also as a proof of the higher direction of study now being pursued in England by amateur microscopists. As a humble member of this numerous class, the present writer ventures to refer to the early date of Mr. Wenham's communications when he stood almost alone as the pioneer of a future micrographic science, and to bear thankful testimony to the practical experience and sterling value of all that he has written. And he also cordially recognises the high aim and zealous study of Dr. R. Pigott, the direction of whose labours must ultimately prove most serviceable to all who desire to understand the real power and possible perfection of their favourite instrument. Any unfair spirit of criticism of matters so little appreciated by some of his critics is to be earnestly deprecated. One can only regret, whilst profiting by the opportunity of hearing all sides of a question, to be reminded of the woeful sentiment "*tantæne celestibus iræ.*" The vexatious partisanship of "aperture" and the disputed estimates of the performance of lenses constructed by this or that maker, must appear as overstrained and even ridiculous to the optician who can best guage his own or any other maker's work, as to those who care only to understand the principles of construction and to form a rational judgment of their action.

It is to be hoped that a more general agreement on the essential parts of the theory of the microscope will soon prevail, and that the exaggerated significance of certain matters too long discussed in our journals, will fade to its proper vanishing point.

The theoretical limits of optical capacity of the microscope.

In "Poggendorff's Annalen," for 1874, Prof. Helmholtz published an article, of which the following is a translation.

Whether, and to what extent, the optical performance of the microscope is capable of further improvement, is a question of the greatest moment for many branches of natural history. Doubtless, some progress, and notably through the revival of Amici's suggestion of immersion lenses adopted and carried out with such success by Hartnack, has been made, but each onward step is slow and faltering. We have, it is clear, arrived now at a point at which any trifling gain is effected with a disproportionate effort of mental as well as mechanical labour. And yet, so far as I can see, no one has been able to give any reason why this should be, excepting the common belief that the difficulty lies in overcoming the spherical aberration of lenses so small and of such quick curvation as is needed for objectives of very high magnifying power. It is not long since Herr Listing, one of the most eminent authorities on this subject, discussed, (Poggendorff's Ann. v. 136,) the means by which it might be possible to obtain amplifications ranging from 25 to 50,000 diameters, whilst in actual practice the ordinary range of *serviceable* amplification is at the present moment limited, to, from 400 to 800 diameters. Moreover the collective experience obtained by repeated efforts of practical opticians has taught us that all high amplifications combined with good definition (i.e., sharp delineation,) are obtainable only by instruments in which the objective admits a cone of light of very large angular aperture from each point of the object.

We have gradually arrived at that stage of improvement in the construction of instruments in which rays of light whose direction is nearly perpendicular to the axis of the instrument are passed into and through the objective, and transmitted towards the ocular. This, it is true, happens only when a lens is used dry (i.e., the front surface in contact with air,) in which case rays inclined to the axis at angles up to 87½° actually do enter a well constructed immersion lens. This angle, however, diminishes to about 48°,* when the lens is used wet, that is when water is dropped between lens and covering glass as in the ordinary practice. This last named angle is nevertheless of far higher amount than any angle of aperture in the lens system of a telescope, or photograph camera, because with such oblique incidence, the spherical aberration, even in the carefully calculated and accurately executed lenses of these instruments would be simply intolerable. Why then, notwithstanding this, is the large incident cone of light in the microscope more advantageous than a narrow one of more intense light which would deliver an equal absolute quantity? The answer hitherto given to this question appears to me unsatisfactory. For the so-called "penetration" (i.e., the power of delineating by light and shadow and so rendering visible to the eye particles whose refractive quality differs but slightly from that of the matter surrounding them,) depends solely upon the proportion of the aperture of *illuminating* cone, to that of the cone passing from points of the object into the lens. Sufficient delineating shadow can only be got by narrowing the aperture of the illuminating cone, and a comparatively large cone can only be applied beneath the object when the cones of light passing from it into the objective are also large.

Now there does, in point of fact, exist in the microscope, a special cause which under the conditions here given produces a far greater aberration of rays from the focal plane than is occasioned by spherical and chromatic aberration, and which makes itself most felt just when the cones of incident light are smallest. This cause is diffraction.

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* These figures it must be borne in mind, denote in each case the angle included between outermost incident ray and axis of instrument, that is *half* the so-called "*angle of aperture.*"

If, perhaps, occasional allusion has been made to diffraction as a cause of deterioration of the microscopic image, I have yet nowhere found any methodical investigation into the nature and amount of its influence, but such an investigation shews, as will here appear, that diffraction necessarily and inevitably increases with the increase of magnifying power, and at length presents an impassable limit to the further extension of microscopic vision which limit, moreover, has been already closely approached in our newest and best instruments.

That diffraction and consequent obscurity of microscopic image must necessarily increase with increasing amplifications of the image, and this quite independently of any particular construction of the instrument, rests as a fact upon a general law which applies to all optical apparatus, and which was first formularised by La Grange * for combinations of any kind of "infinitely thin" lenses. This law has apparently remained almost unknown, perhaps because La Grange enunciated it in equations whose co-efficients have not characters which readily present clear ideas to the mind. In my treatise on physiological optics, I have given expression to this law in a somewhat more general form, namely, for centred systems of refracting curved surfaces with any singly refracting medium between them, and have endeavoured to formularise it in readily intelligible physical characters. I shall therefore recapitulate as briefly as possible this theorem and its demonstration. It holds good for every centred system of spherical refracting or reflecting surfaces through which rays pass with angles of incidence so fine as to form punctiform images of punctiform objects; that is to say refracts homocentric rays, homocentrically.

By the term, centred system, I designate one in which the centres of the curves of each refracting or reflecting spherical surface lie in the same straight line, the "axis" of the system. In front of such a system, and situate in its axis, let us suppose a luminous point belonging to some object lying in a plane at right

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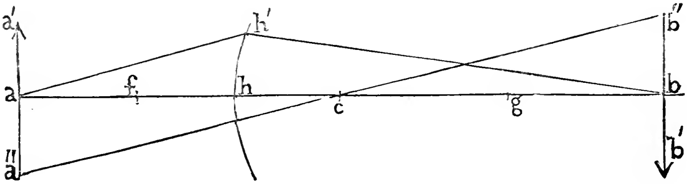
* Sur une Loi general d'Optique—Memoires de l'Academie de Berlin 1803.

angles to the axis, and from which rays pass through the system. The angle formed between any one of such rays and the axis, we shall call the divergence-angle of that particular ray. Any plane supposed to extend through the axis and along the ray, constitutes the incidence plane of that ray at the first refraction and will include, therefore, the same ray after its next refraction, and consequently after every subsequent refraction. Of this plane which will be divided in crossing the axis into two halves, one half will be treated as positive, the other as negative, and in correspondence therewith, the divergence-angle of the ray as positive or negative, according as the ray proceeds towards the positive or negative half of the plane. These postulates being settled the rule may be thus stated :—

THEOREM.

In a centred system of spherical refracting or reflecting surfaces the product of the divergence-angle of any ray, the refraction index of the medium through which that ray passes, and the magnitude of the image to which the rays passing through that medium belong, remains unchanged by every refraction, provided always that the conditions of production of an accurate image are duly preserved. This product will therefore have the same value after emergence of the rays as it had before they entered the system of lenses.

DEMONSTRATION.



Let a b be the axis of a lens system.

— h h' —— one of the refracting surfaces.

— c the centre of its curve.

Let a be the point of convergence of rays, incident on $h\,h'$.
— b ———— re-union of rays refracted by $h\,h'$.
— f the front principal focus.
— g the back ————

Further let n' represent the ratio of refractions of the medium in front of hh'

n'' represent the ratio of refractions of the medium behind hh'

a' the positive divergence-angle $h'ah$ of the ray passing in first medium through h'

a'' the negative divergence-angle, in second medium $-h'bh$

β' the magnitude of image aa'' belonging to the rays of the first medium.

β'' the magnitude of image $-b'b''$ belonging to the rays of the second medium.

Firstly we have from similarity of triangles $aa''c$ and $bb''c$

$$\frac{\beta'}{\beta''} = -\frac{ac}{cb} \qquad (1)$$

Again, if we consider the short arc hh' of the refracting surface as a straight line at right angles to the axis ab

$$hh' = ah.\ \text{tang.}\ a' = -\ bh.\ \text{tang.}\ a''$$

Or substituting the angles for the tangents which is allowable here on account of the smallness of the angle:

$$\frac{a'}{a''} = \frac{bh}{ah} \qquad (2)$$

Multiplying equations (1) and (2), we get

$$\frac{a' \,.\, \beta'}{a'' \,.\, \beta''} = \frac{ac \,.\, bh}{bc \,.\, ah} \qquad (3)$$

Now according to the known laws of refraction at a spherical surface, whose radius $hc = r$, the value of their principal focus is

$$F' = hf = \frac{n'\ r}{n''-n'} \qquad F'' = hg = \frac{n''\ r}{n''-n'} \quad (4)$$

From which follow

$$\frac{F'}{F''} = \frac{n'}{n''} \quad (4^{a})$$

$$F'' - F' = r \quad (4^{b})$$

Further

$$\frac{F'}{ah} + \frac{F''}{bh} = 1 \text{ and } \frac{F''}{ac} + \frac{F'}{bc} = 1$$

Or

$$\frac{bh}{ah} = \frac{bh-F''}{F'} \text{ and } \frac{bc}{ac} = \frac{bc-F'}{F''}$$

Division of the last two equations gives

$$\frac{bh\ .\ ac}{ah\ .\ bc} = \frac{F''\ (bh-F'')}{F'\ (bc-F')}$$

But by equation (4^{b})

$$bh = bc + r = bc + F'' - F'$$

And

$$bh - F'' = bc - F'$$

Hence

$$\frac{bh\ .\ ac}{ah\ .\ bc} = \frac{F''}{F'} = \frac{n''}{n'} \text{ according to equation } (4^{a})$$

Therefore equation (3)

$$\frac{\alpha'\ .\ \beta'}{\alpha''\ .\ \beta''} = \frac{n''}{n'}$$

Or

$$n' \,.\, a' \,.\, \beta' = n'' \,.\, a'' \,.\, \beta'' \qquad (5)$$

q. e. d.

From this theorem it follows—

(Firstly), that when a ray (B) proceeding from a luminous point has an absolute smaller divergence-angle than the ray A, the divergence-angle of B will, after subsequent refraction, remain always less than that of A, because the product obtained by our theorem for B is from the beginning less than that obtained for A, and for the same reason must continue to be smaller after each refraction.

(Secondly), when two rays, starting from the same point on the axis, with equal angles of divergence, but following planes which extend in opposite directions through the axis, their divergence-angles continue to be equal after each refraction, a result which appears indeed at once evident from the symmetrical disposition of a lens system round its axis.

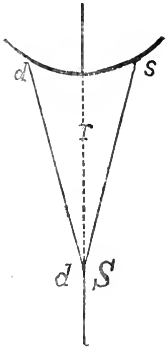
If now we imagine the illuminating rays, on their way to the object, to be circumscribed by interposing a diaphragm pierced with a circular opening whose centre coincides with the axial line, the plane of the diaphragm being at right angles with the optical axis, then those rays which pass through the opening close to its margin have all alike the largest divergence-angle, and retain the same relation after each fresh refraction. These rays obviously occupy the exterior outline of cones having a circular base, and whose axis is the optical axis of the lens system, and they constitute the boundary of the cone of light proceeding from the luminous point. The divergence-angle of these border rays is, in this case, throughout their entire course, the angle which the semi-aperture of the conical surface bounding the illuminating cone, measures.

From this there follow, (firstly), certain important results in regard to the *photometric* conditions of the microscope image.

According to known laws of photometry, we may equate L the quantity of light sent forth from the luminous point $d\,S$ upon another point $d\,s$, whose distance is r as follows where (r,N) and (r,n) represent the angles formed between the line r and the normals N and n.

$$L = J\frac{d\,S\,.\,d\,s}{r^2}.\ \cos\,(r,N)\ .\ \cos\,(r,n) \qquad (6)$$

If now we understand by $d\,s$ the circular aperture of the cone of rays at one of the refracting surfaces, and by $d\,S$ a luminous point intersected by the axis so that r falls in the axial line.



Then $\cos.\,(r,n)=1$, and $d\,S\,.\,\cos.\,(r,N)$ is the projection of $d\,S$ on a plane normal to the axis.

Let a be the angle of divergence of the rays directed to the periphery of $d\,s$, then $d\,s = \pi\,.\,r^2\,.\,a^2$.

$$L = J\,.\,\pi\,.\,a^2\,.\,d\,S\,.\,\cos.\,(r,N) \qquad (6^a)$$

The same amount of light must also be contained in the same cone of rays continued through the following medium. And if we indicate the corresponding quantities by the signs J', a', dS', $N_,$ then

$$L = J'\ .\ \pi a'^2\,.\,dS'\,.\,\cos.\,(r,N') \qquad (6^b)$$

Now, dS' is the image of $d\,s$, and its projection—normal to the axis—$dS'\,.\,\cos\,(r,N')$ is the image of the corresponding projection of dS. We have therefore the proportion

$$dS\,.\,\cos\,(r,N) : dS'\,.\,\cos\,(r,N') = \beta^2 : \beta'^2$$

From which follows

$$J\,.\,a^2\,.\,\beta^2 = J'\,.\,a'^2.\,\beta'^2 \text{ and by equation } (5)$$

$$J : J' = n^2 : n'^2. \qquad (6^2)$$

This gives the brightness with which the surface of image included within the outline of the illuminating cone shines, independent of the direction which dS and dS' have in relation to the axis, and of their distances from the surface of the curve (of lens.)

From this image (dS') we might pass on to consider a second, dS'', and so forth. It is obvious that between each following image and dS a similar equation would arise.

If we suppose the object and the image to lie in the same medium, then *the brightness of the optical image produced by rays which incline at very slight angles to the axis and perpendicular will always be equal to* (i.e., *neither more nor less than) the brightness of the object, except in so far as loss of light by reflection and absorption may occur.*

But this law should hold good without limitation of divergence-angle. For if it were possible to throw an image of any bright point sending forth its light according to the conditions above expressed, (namely, of rays circumscribed by a diaphragm aperture) which image should shine with greater intensity than the rule above given admits; then we could cause this bundle of rays to pass on as parallel rays through a plane end-surface into the air, and to fall into the eye of an observer; and in such case it would happen that an object would be seen more brightly illuminated through an optical instrument than it was before,—a thing contrary to all experience, whatever kind of transparent refracting material be used. Now, if this were possible with light it would also be true of heat, as might be shewn by application of similar reasoning; and then the law of equal radiation of bodies possessing equal temperature would be impugned.

But the equation which premised very slight divergence-angles of incident rays may be more precisely formulated, and so express the same result in the case of wide divergence-angles.

A more precise expression of the law of divergence-angles.

In equation (5) it is a matter of indifference whether we substitute for α its sine or tangent or similar functions which for indefinitely small α would be its equivalent. If we assume larger divergence-angles of a pencil of rays whose section is a circle, then

$$L = JdS\int_0^a 2\,\pi.\ cos\ a.\ sin\ a.\ da = \pi\ JdS.\ sin\ ^2a.$$

If after a series of refractions the surface $d\ S_1$ is completely and accurately imaged in $d\ S_1$ with the brightness $\frac{n_1^2}{n^2}\ J_1$ and a_1 of the respectively appertaining divergence-angles; then the amount of light must be

$$L = \pi\ J\frac{n_1^2}{n^2}.\ d\ S_1\ .\ sin^2a_1.$$

as now, $dS\ :\ dS_1 = \beta^2 :\ \beta_1^2$ there follows from these equations,

$$n\ .\ \beta\ .\ sin a = n_1\ .\ \beta_1\ .\ sin\ a_1 \qquad (7)$$

which renders this formular of equation (5) valid for larger angles of divergence, assuming that β and β_1 are two images exactly reproducing each other, and whose surfaces are perpendicular to the axis.

Brightness of Image. When the pupil of the observer's eye is fully immersed in the pencil of rays proceeding from any point of an image, the observer will see the image illuminated as brightly as the object. This result was already announced by Lagrange. Unfortunately he had not investigated a second case, which happens to be more common just when high powers are used, namely, when the pencil of rays does not entirely occupy the pupil of the eye.

If a pencil of light having only small divergence-angle a_1 does not entirely fill the pupil when the image β_1 is situate at the proper distance of distinct vision, then the brightness H of the retinal image in that eye will be less than that entering the free eye H_0, whose pupil is entirely filled with light.

Let s indicate the distance of vision, p the radius of the pupil, then the area of its surface will be $\pi\ p^2$, the cross section of the pencil of light $\pi\ s^2.\ \sin^2 a_1$ and the general relation will be

$$H : H_0 = s^2.\ \sin^2 a_1 : p^2$$

Or using equation (7)

$$H = H_0 \cdot \frac{s^2}{p^2} \cdot \frac{n^2}{n_1^2} \cdot \frac{\beta^2}{\beta_1^2} \sin{}^2\alpha.$$

The last medium in front of the eye must necessarily be air, therefore $n_1 = 1$, and if we indicate by α_0 the angle of divergence of the instrument measured in air according to Lister's method, then $\sin \alpha_0 = n \cdot \sin \alpha$. Putting the amplification $\frac{\beta_1}{\beta} = N$, then

$$H = H_0 \frac{s^2 . \sin{}^2\alpha_0}{p^2 . N_2}$$

With an amplification N_0 by which the cone of light just fills the pupillary opening, and which we shall call the normal amplification of the instrument, $H = H_0$. Hence

$$N_0 = \frac{s}{p} \sin \alpha_0 \qquad (8)$$

And if α_0 remains constant,

$$H : H_0 = N_0^2 : N^2. \qquad (8^a)$$

If as was assumed

$$N > N_0$$

Whilst $H = H_0$ when $N \leqq N_0$.

That is to say.

The brightness of an image seen through the microscope is equal to that of light filling the unoccupied eye when the amplification is less than*

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* Daylight is of course supposed, and a monocular microscope in use.

(or not greater) than the "normal" amplification, (*i.e.*, when the area of the ocular image just fills the pupil) *otherwise, with the same constant divergence of incident rays, the brightness is inversely proportional to the amplification of image.*

The normal amplification increases with the increase of the sine of the divergence-angle whose greatest value is 1 when this angle approaches a right angle, (as is the case with the widest-angled objectives).

Assuming 10 inches as the distance of clear vision for calculation of the amplified image, and $1\frac{1}{2}$ mm. as radius of pupil for bright illumination, the normal amplification is represented by the figures 166.7, and the brightness of image follows the following rates:

For an amplification of 333.3 .... $\frac{1}{4}$ brightness.
,, ,, ,, 500.0 .... $\frac{1}{9}$,,
,, ,, ,, 666.7 .... $\frac{1}{16}$,,

Which shows how rapidly the brightness must necessarily decrease with increasing amplifications.

Were it possible to conduct a hemispherical cone of light from an object lying in water into an immersion lens, and form therewith a correct image, all these amplifications might be raised in the proportion 1.335 to 1 whilst the brightness of image remained the same. But, as already remarked, every instrument hitherto constructed admits in air only, and not in water, a cone of incident light at all approaching to the hemispherical (180°).

The sectional area of the pencil of light entering the pupil may be determined empirically with ease. Focus the instrument on a bright field, and withdraw the eye from the ocular (keeping the direction of the axis of the microscope) and look at the ocular itself. Just in front of it will be seen a small bright circle against a dark ground. This is the optical image of the objective lens which the ocular (*i. e.* chiefly its field glass) forms. All light which comes through the objective and has passed the ocular must be collected in this image of the objective. It corresponds, therefore, to the area in which the several cones of light, transmitted from the bright points of the object, are collected at this spot. To gather all this light and thus get the largest and clearest field of vision, the pupil of the eye must be brought to this spot. The relation between the area of the image and that of the pupil gives at once the ratio by which the brightness of the image is less than that of the object when looked at with the unarmed eye. The same brightness of image as of object exists only when the size of the image is equal to, or larger than that of the pupil.

In the instance of the telescope, Lagrange had already stated that the relation of size between the diameter of the objective and that of the picture of the objective formed by the ocular, is directly as the amplification, and he proposed to employ this ratio as a means of determining the amplification. With the telescope, however, such a decrease of brightness is not a necessary accompaniment of increased amplification, because the amount of incident light may be augmented indefinitely by enlarging the object glass or reflector. The aperture of the cone of light entering the microscope is, on the contrary, definitely restricted by the limits of the angle measuring that aperture.

So far, our demonstration shows that the relation between brightness of image and amplification is entirely independent of any particular construction of the instrument, provided only that it gives well defined images. An increase of amplification would only be possible, therefore, when a more intense illumination, *e.g.*, direct sunlight were employed, as indeed Listing had in view in the methods proposed by him for obtaining enormous amplifications. But here other difficulties present themselves, which arise from the very slight divergence-angle of the emerging rays, as appears in all cases of high amplification from the conditions of the equation representing the course of rays that enter an objective with wide divergence-angle.

The first difficulty is, that shadows of entoptic objects throng the field more densely as the area of this field at the eye spot (ocular image of the objective) becomes smaller. The retina is illuminated from this area as if it were the source of light from which proceeded all the rays that enter the eye. This area is at the same time the basis of the collective pencils which belong to the several points of the object, and of its image on the retina, and its diameter, as before shown, varies in inverse proportion of the amplification. But the very conditions which must be fulfilled in order to obtain sharply defined shadows of objects within the eye are exactly what occur here, namely, that a strong light should enter the eye from a relatively small surface.

Whoever has, at any time, attempted to illumine the field of the microscope with direct sunlight, when employing a high amplification, will remember the peculiar spotty appearance of the field so obtained. Some of these spots remain fixed in the field, but others move with the motion of the eye. The first class of spots is due to dirt particles or imperfect polish of the ocular lenses; the second arises from shades caused by intervening opacities in the tissues of the eye—conjunctiva, cornea, crystalline lens, or vitreous humor.* This method has even been used to discover their existence, and is, in truth, a very suitable one. In proportion, however, as entoptic objects become more noticeable, will a greater number of finer details, of microscope objects become obscured.

A second and inevitable disadvantage arising from the narrow divergence angle of the emerging rays shews itself in the occurrence of *diffraction phenomena,* whereby the outlines of visible objects are effaced, and at the same time doubled or further multipled. We have to deal here chiefly with diffraction phenomena as they appear when we look through a minute circular opening. A bright point of light (reflection of sun on the bulb of a thermometer), viewed through a pin point hole pierced in a card appears as a bright disc surrounded by alternate bright and dark circles. The apparent breadth of these rings, reckoned from minimum to minimum, corresponds very nearly to a visual angle, whose sine is equal to $\frac{\lambda}{a}$ where λ expresses the respective wave length of the light, and a the diameter of the opening. The outermost rings have exactly these dimensions, the

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* But mainly from the retinal vessels, as shown by Heinrich Muller, vide Wurzburg Verhandlungen, Vol. 5, Page 411.—H. E. F.

inner are a little wider, and the radius of the innermost bright ring is $1{\cdot}220\frac{\lambda}{a}$. Now, as the smallest visual angle under which we can possibly distinguish two fine bright lines from each other may be fixed at 1 minute, the figures of the brightest yellow-green light, whose wave length = 0·00055 m.m., will be visible when d = 1·89 m.m. Even with a somewhat larger opening the dispersion of a bright point into a circle or of a bright line into a streak must be noticeable.

When we look through such an aperture at any object which shows luminous points, the diffraction figures of the separate points partially cover each other, so that the fringe of dispersion circle of each single point, taken by itself, may not be recognisable. The effect, however, of this diffraction, since it changes every point into a small dispersion circle, obviously causes effacement of the true outline, just as happens when the accommodation of the eye is imperfect, in consequence of which very minute objects, which can be perceived only when the image on the retina is sharply defined, are unrecognisable. We may convince ourselves that this is the fact by a simple experiment. The retina is most sensitively impressed by such objects as gratings, consisting of alternate dark and light parallel lines, whether printed on paper, or made of wirework or drawn on glass. Let the observer place himself at such a distance from the grating that, with the aid of spectacles giving perfect accommodation of the eye, he may just be able to distinguish the bars or lines separately from each other. Then let him place before his eye a card in which fine apertures of different diameters have been pierced, and observe whether he still sees the lines or sees them as well with as without the card. The grating must be brightly illuminated (*e.g.*, by exposing lines printed on paper to direct sunlight), in order that the picture seen through the aperture may remain sufficiently bright. On trying the experiment myself, I find that a notable deterioration of the image is caused by an aperture of 1.72 m.m. diameter, and the deterioration is much more striking with still narrower apertures.

Instead of a series of lines printed letters may be used, the same conditions being fulfilled, namely, by observing the point at such a distance that the single letters may be just distinguished. On looking at them through an aperture of 1 m.m. diameter, they will be scarcely or not at all legible. This experiment is, however, not so sensitive as the first. But, in all cases, the best accommodation of the eye must be carefully maintained, otherwise the act of passing a card, pierced with an aperture, before the eye may, when there is imperfect accommodation, actually improve vision by diminishing the dispersion.

The theory of diffraction of rays in the microscope leads, as will be shewn in the following pages, to the conclusion, that any single point of light in *the object* must, when viewed through the microscope, appear exactly, as if an actual luminous point, situate in the *image of the object*, were observed through an aperture corresponding in size and position to the ocular images (at the so called eye spot) of the respective narrowest diaphragm aperture.

Hence it follows, firstly—that diffraction phenomena must be visible when the ocular image has a diameter less than 1·89 m.m., and that the size of the dispersion circle, caused by diffraction, must increase in inverse proportion to the diameter of this ocular aperture, consequently in direct proportion to the amplification, supposing that the incident light from each point in the object remains unchanged. Under such circumstances then, the image will not, even with higher amplifications, suffer *further* loss of sharpness of outline from diffraction, inasmuch as the dispersion circles preserve, throughout, the same relation to the apparent magnitude of the object. On the other hand, the deterioration arising from diminished brightness and multiplication of darker entoptic shadows, must increase with the amplification. From this it follows, therefore, that, as a general rule, that amount of amplification will shew most detail by which the minutest points that are visible at all in the image, shall be presented under the most suitable visual angle, namely, somewhat larger than that at which an observer can distinguish the minutest objects visible to him under any circumstances.

Calculated by the equation before mentioned, the diameter (1·89 m.m.) of the area of light-rays entering the pupil, when the light incident on the objective (in air) spreads out to nearly 180°, corresponds to an amplification of 264½. For objectives with less aperture the amplification must be set down at a lower figure. In H. v. Mohl's handbook of the microscope it is stated, that amplifications varying between 300 and 400 allow most detail to be seen, whilst Harting, speaking of more recent instruments with large angular aperture, found amplifications of 430 to 450 most serviceable.

If now it be required to determine the magnitude of the minutest recognisable object as a standard by which to measure the accuracy of the microscopic image, we must not take for our unit the measured diameter of such objects as bright single spots or lines on a dark field, or vice versa, for the reasons which I have already given in my handbook of physiological optics (p. 217), in discussing the capacity of the eye for distinct vision. For, in the cases above mentioned the result depends not only on the proportional magnitudes of the images, but also on the susceptibility of the retina to slight differences of light. The most suitable objects are, here also, fine gratings which shew alternate clear and dark stripes. Such indeed are in common use, as in the examples of Nobert's lines, and the line-systems of diatoms and insect scales. But as the light of the bright stripes is doubtless strongly dispersed before it becomes quite undiscernable, dependence can be placed only on the measurement of the space between the centres of two contiguous stripes, and not upon the measurement of space occupied by the stripes (wide or narrow) as originally distributed. I select, therefore, as the measure of the minutest distinguishable objects, that smallest appreciable interspace between the centres of two contiguous stripes by which these stripes can still be recognised as separate.

When diffraction is caused by a fine network of square meshes, it can be proved that the network must appear as a uniformly illuminated surface when the breadth of fringe of diffracted light is equal to that of the open space of the network. For circular meshes, the integration for calculating the distribution of light is tediously diffuse. When the diameter of a circular mesh is equal to the length of one side of a square mesh, the outmost fringes in the spectrum of a bright spot are of equal width, but the innermost fringes are wider in the circular meshwork. If, therefore, the fringes of the square meshes are so broad as to efface all impression of separate bright lines of the network when the measured widths of fringe and mesh are equal, the same thing must happen with the circular meshwork, a portion of whose diffraction-fringes is still wider. For this reason I have, in the following demonstrations, taken the width of the outermost fringes of a circular meshwork as the lower limit of distinguishable distances in an object. It is not, however, impossible that by some fortuitous overlapping of images, objects of still smaller dimensions might, occasionally, be half seen, half guessed at. But safe and certain recognition will scarcely be possible.

Let now—

ε be the magnitude of the smallest recognisable interspace

λ wave length of the medium,

α divergence angle of the rays incident in that medium,

λ_0 α_0 the values of the last named magnitudes (λ and α) for air,

Then by the formulæ deduced in a subsequent page—

$$\varepsilon = \frac{\lambda}{2 \sin \alpha} = \frac{\lambda_0}{2 \sin \alpha_0}$$

For white light we may, as before, take the wave length of the medium bright rays.

$$\lambda_0 = 0.00055 \text{ mm.}$$

If $\alpha_0 = 90°$ then $\varepsilon = \frac{\lambda_0}{2} = 0{\cdot}000275$ mm. $= \frac{1}{3{,}636}$ mm. or $\frac{1}{92{,}000}$ inch.

Were it possible to obtain with an immersion lens, the transmission of rays = 180° of divergence aperture (in water) a would then $= 90°$ and λ nearly $\frac{3}{4}\,\lambda_0$

$$\text{and hence } \varepsilon = \frac{1}{4{,}848}\text{ mm.} = \left(\frac{1}{122{,}000}\text{ inch}\right)$$

According to measurements of Harting (published in vol. 114 of Poggendorf's annals), the magnitude of the smallest distances taken with No 10 objective of Hartnack, reckoned by our formula is

$$\varepsilon = \frac{1}{3{,}313}\text{ mm.}$$

The figures $\frac{1}{5210}$ mm. given by Harting refer to the width of the dark space *between* the lines. In close accordance with the above are the measurements by Herr L. Dippel (in his work on the microscope, Brunswick, 1867), of fine diatoms, who found that the closest series of lines that he could distinguish $= \frac{1}{3500}$ mm., and the finer Nobert lines $= \frac{1}{3600}$ ($\frac{1}{90000}$ inch). Earlier measurements 1853, of Messrs. Sollitt and Harrison (Quarterly Journal Microscopical Society, vol. 5, p. 62) count much higher. Recognisable lines Navicula Arcus are said to have been counted at 5120 to the mm. ($\frac{1}{129000}$ inch). This far exceeds the theoretical limits for objects in air. But since all later measurements remain much lower than these, I do not know that they are trustworthy. Harting, also, who cites them doubts their accuracy.

Besides, any possible further increase of angular aperture in the case of objects lying in water, the capacity of performance might, perhaps, be increased by employing blue rays only.*

In photography, blue light is chiefly active, and photographs appear actually to perform more than the eye can with white light. In a photograph of Surirella gemma, executed by Dr. Stindi, with an objective of Gundlach's, giving $\frac{1000}{1}$ amplification, lines are

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* Hartnack makes an illuminating apparatus for use of blue rays only, and exhibited it in the Vienna Exhibition, 1874.

visible which may be counted at 3800 to 4000 in the millimeter ($\frac{1}{100000}$ of English inch.)

Thus it appears to me beyond doubt that diffraction of the rays is the the principle cause of the limitation of sharpness of the microscope image. In comparison with diffraction, chromatic and spherical aberrations appear to exert but an inconsiderable influence, in spite of the very large angles of incidence and divergence of rays. Considering the extreme care expended on calculation and execution of lenses for telescopes and the photograph-camera, it is justly a matter of surprise that with the lenses of the microscope, which are so much more difficult to construct according to prescribed dimensions, and which have so large an aperture, spherical aberration makes itself so little felt. I have, however, already pointed out that when there is water between the object and covering glass, and also between this and the objective, the divergence angle is not 87½°, as usually stated, but only 48½° With dry mounted objects an angle of 87½° can indeed be in action, but *only through the minute distance between the object and covering glass*, so that the spherical aberration arising therefrom is of no importance.

As wide pencils of light are needed to keep diffraction within moderate limits, the illuminating apparatus should also be capable of emitting pencils of the same angle, in order to show clearly the contour lines of dark objects.

If there happen to be particles in the object which act like lenses, these may of course convert a small illuminating pencil of rays into strongly divergent rays, and so become clearly visible. Otherwise nothing is seen but a confusion of diffractions at and in the object on one part, and in the (optical) aperture of the microscope on the other part.

Here lies obviously the explanation why microscopes, otherwise good, but whose illuminating apparatus is not specially arranged for the purpose, yield, with artificial illumination, *e. g.* a flame, such unserviceable images of the outlines of dark objects. For an immersion lens, the best illuminating apparatus is one constructed according to the same principle—that is to say, a lens of the same kind reversed. The readiest mode of finding whether the illuminating apparatus gives sufficiently wide pencils of light is to examine the ocular image with a magnifying lens after the instrument has been focussed.

I must now relate here the *failure of an attempted improvement*, the negative result of which is significant. I thought myself justified in inferring theoretically, that the diffraction of the microscope might be neutralised if the points of the narrow aperture which causes this diffraction were made singly and separately luminous, and that this could be affected by causing a sharply defined optical image of the source of light, (*e.g.*, sun illumined cloud,) to be thrown by a lens on the plane of this aperture. Years ago I tried experiments of this kind on a Nobert microscope, provided with immersion lenses, giving excellent definition. The result of this trial shewed that it was perfectly indifferent whether the image of the source of light fell on the plane of the object, or of the objective. The diffraction fringes caused by the use of a very deep ocular remained uncorrected. More recently I have convinced myself by fresh trials made with larger lenses, that such a procedure is useless. When a good achromatic lens of about 18 inches focus, is so placed as to show a sharp image of the source of light, (as in this case a bright sky cloud,) upon the surface of a system of lines scratched on glass, the images of many separate luminous points will be thrown upon the variously transparent clefts of this grating, and it might be supposed that the interference of rays which had passed through neighbouring clefts would cease. If however we look through the grating towards the lens, and place before the lens pieces of card pierced with fine slits, we see with the naked eye just the same diffraction fringes, as well at these slits as at the outer edges of the cards, as would be seen if the lens were removed, or the grating set out of focus.

Instead of the lines I then made trial of two fine linear slits cut in cardboad, with an interspace of about one m.m. and through which I could see with the naked eye a system of very fine interference lines belonging to the diffraction image of another slit which was cut with the lines at a very small acute angle, sufficiently narrow to produce the interference lines at the point of this angle. But these did not disappear when I threw an optical image of the incident light on the plane of the double (parallel) slit. In this experiment not the slightest suspicion could be entertained that chromatic, or spherical aberration had dispersed the rays over an interspace of 1 m.m. width. The only explanation I can offer, is, that the light from the lens which passed through the acute angle of the slit serving here as object, suffers so strong a diffraction that it subsequently reaches the two openings of the doubly-slit card with a corresponding wave-phase and therefore sends interfering bundles through both openings. In order to be able to see the interference lines, it is necessary that their minima shall appear at a wider distance from each other than the width of the lines of which they are images, and when this condition is fulfilled theory does in fact shew that the central clear portion of the diffraction figure of the simple slit forms a line of light which is broader than the distance between the two slits of the doubly-slit card.

Similar relations take place (although more difficult to subject to calculation,) when the fine edge of a dark screen is used as the object. It is known that from such an edge, bundles of interrupted rays (in linear formation) likewise bend themselves into the dark field, which have corresponding phases of movement, and so when bent by a second screen can exhibit regular interference. That the resultant effect cannot become *nil*, appears clearly from the fact that the effect of a bright line may be represented as the product of the action of two endless half-planes bounded by straight lines the edges of which half-planes slightly overlap each other, minus the action of an equally bright whole plane. As the latter causes no interference phenomena, the bright line of itself could not cause interference in any part of the field, unless each of the half-planes also produced such interference. It follows therefore that the light bent away from a straight edge must also spread itself out with notable strength to the same width as would the light from a slit in the card bounded by two other slits.

THEORY OF DIFFRACTION IN THE MICROSCOPE.

In conclusion I shall here shew a method by which the diffraction of rays passing through the microscope may be theoretically calculated. Instead of the simple lengths of rectilinear rays, as taken into consideration by the theory of diffraction of light which passes through one medium only, the *optical lengths* of the rays must be taken, that is to say, the lengths obtained by adding together the product of each portion of a ray multiplied by the index of refraction of the medium through which it passes.

The wave phases of two rays that have started from the same luminous point, and have equal optical lengths, are also equal at the other terminal point, because the wave lengths in different media are inversely proportional to the refractive indices. Further, it is known* that the optical length of all rays between two conjugate foci of the same pencil in which a perfect re-union of these rays is accomplished is equally great.

In order to calculate the diffraction through the (relatively) narrowest aperture of the microscope, each point (*c*) in the plane of this aperture must be treated as a ray centre whose phase is determined by the optical length of the normally refracted ray, which, starting from the luminous point (*a*), has arrived at *c*. This length I designate with *ac*. On the other hand, the difference of phase between *c* and the point *b* in the surface of the image whose brightness is to be determined depends on the optical length *cb* found for the normally refracted ray travelling from *c* to *b*. The phase of movement continued from *a*, through *c* as a new centre of the ray, to *b*, will, therefore, depend on the sum of the optical lengths $ac + cb$. The share which this ray has in

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* The proof of the law here adduced is to be found in my *Handbook of Physiological Optics*, and elsewhere.

the movement in the point b will be given by an expression in the form

$$A \ sin. \left\{ \frac{2\ \pi}{\lambda} \left[ac + ab - at\right] + Const \right\}$$

Where λ is the wave length in empty space, A the speed of progressing movement, t the time. The sum of these quantities taken for every point c of the aperture (in which the factor a can be considered as approximatively independent of c) will finally determine the movement at b.

If now we suppose the rays passing from (a) and (b) to the point (c) of the relatively narrowest aperture to be prolonged in the direction which they have at the point (c) until they intersect each other in the points (α) and (β), these last points will be the images of the points (a) and (b), formed in the medium of (c). Since, then, from what has been said above, the optical lengths ($a\alpha$) and ($b\beta$) being lengths measured between conjugate foci, are constant, we may put

$$(ac) = (a\alpha) - (c\alpha)$$
$$(cb) = (\beta b) - (\beta c)$$

The direction of movement of the ray must be conceived as always advancing from the first to the second letters; and therefore,

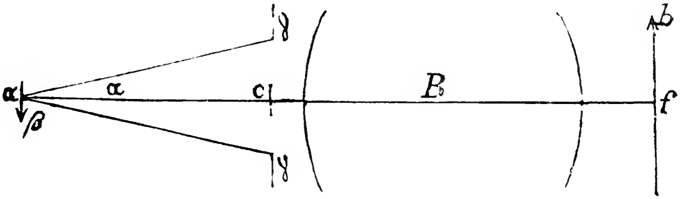
$$(c\alpha) \text{ be put } = -(ac) \text{ as also } (\beta c) = -(c\beta)$$

Then the expression for the effect of each separate ray on the point (b) becomes

$$A \ sin. \left\{ \frac{2\pi}{\lambda} \left[(ac) - (\beta c) - \frac{t}{a} + (a\alpha) + (\beta b)\right] + \ Const \right\}$$

The only terms amongst the signs bracketed under the sine that vary with the point c are $(ac)-(\beta c)$. These optical lengths, however, lie wholly in the medium of (c), and are, therefore, straight lines; consequently, the diffraction effect of the light from (a) at the point (b), apart from the factor A, which expresses its total intensity, will be the same as that of the light from α for the point β. But the latter can be calculated according to the known method valid for rectilinear rays.

FIG. 2.



Let $\gamma\,\gamma'$ be the relatively narrowest aperture, and (c) its middle point, B the portion of the optical system immediately behind this aperture, and let α be the image of the axis point a of the object; further, let $\alpha\,\beta$ be its image lying in the medium $\gamma\,\gamma'$ and $f\,b$ the image formed by B in the last medium.

When light proceeds from α, and is viewed through the aperture $\gamma\,\gamma'$ whose radius is ρ, interference fringes will appear around α, in which the distance δ between each two neighbouring maxima, (excepting the two first) will be according to known laws, if as before, α represents the divergence angle $c\,\alpha\,\gamma$, which by assumption is very small.

$$\delta = \frac{(\alpha\,c)\,\lambda}{2\,\rho} = \frac{1}{2}\;\frac{\lambda}{\alpha}$$

If N be the amplification of the image $b\,f$ in comparison to $\alpha\,\beta$, the breadth of fringe δ' of $b\,f$ will be

$$\delta' = N\,\delta = \tfrac{1}{2}\,N\frac{\lambda}{a} \quad (8)$$

or as $N = \frac{n\ a}{n'\ a'}$ when a' expresses the divergence-angle of the emergent ray, n' the refractive index of the last medium, n that of the medium at (c).

$$\delta' = \frac{n}{2n'} \times \frac{\lambda}{a'} \qquad (8^a)$$

If $n = n'$ then the form in which this value of the breadth of fringe of image $b\,f$ is expressed is exactly analogous with that for $a\,\beta$, and shows that the fringes in the last image are of just the same dimensions as if seen through the aperture which determines the divergence-angle a' of the cone of rays $\gamma\ a\ \gamma$ or in other words, through the ocular image of narrowest aperture.

The above demonstration pre-supposes that the relatively narrowest aperture of diaphragm is situate where the divergence angles of the pencil of rays are very small. It may however be situate at any part of the instrument. With an immersion microscope this condition is indeed not fulfilled when the surface of front lens is the relatively narrowest aperture. But it would be fulfilled if the aperture were situate on the upper side of the second or third lens. Thus if there were no lateral outspread of the advancing rays on their passage through the front lens of the objective where the pencil is still diverging strongly, then from the point where the divergence is weak, or convergence commences, its lateral limitation, whether occasioned by a diaphragm actually situate at the place, or only conditioned by the previous course of the rays, must nevertheless produce a diffraction.

As regards the final result, it makes no difference whether the aperture at the circumference of the pencil of rays be supposed to be situate a little more to the front or to the back. The image of this aperture formed by the ocular lenses will be very slightly larger when it is situate at the back lens than when it lies in the front lens, but the difference is without any practical significance.

In equation (8) δ' is the breadth of fringe in the last image, a the divergence angle in the medium where the aperture lies, λ the wave length at the same place, N the amplification of the last image, as distinguished from that formed by the rays passing the aperture.

If, on the other hand, we put N_1 for the amplification of the last image referring to the object λ_1, and n_1 for the wave length, and refraction index for the medium in which the object lies, we may according to equation (7) make as a is, by assumption, small

$$\frac{n_1}{N_1} \sin. a_1 = \frac{n}{N} \cdot a.$$

a_1 is the divergence angle in the first medium.

Putting the value of $\frac{a}{N}$ in equation (8) it becomes

$$\frac{\delta'}{N_1} = \frac{1}{2} \lambda \frac{n}{n_1} \cdot \frac{1}{sin\ a_1} = \varepsilon$$

or, as $\lambda\ n = \lambda_1\ n_1 = \lambda_0\ n_0$, which last refers to air medium, we have

$$\frac{\delta'}{N_1} = \frac{\lambda_1}{2\ sin\ a_1} = \frac{\lambda_0}{2\ sin\ a_0} = \varepsilon$$

This ε is the true magnitude of those lengths in the object, which in the magnified image of the fringes appear equal, and will, therefore, be effaced. Therefore, ε may be considered the measure of the smallest distinguishable distances in the object. ε will be smallest when a_0 is largest,—that is to say, when amounting to a right angle. In that case

$$\varepsilon = \frac{1}{2} \lambda_0 \qquad (9)$$

This determination of limit is likewise, as may be seen, independent of the construction of the optical instrument. It holds just as valid for a photographic apparatus as for the relation of the microscope to the eye of the observer. These are the formulæ which were applied in the calculations previously given.

On Aperture and Definition of the Microscope Object Glass.

By DR. H. FRIPP.

SINCE the MSS. of the foregoing translation (completed sixteen months ago) of Professor Helmholtz's essay was sent to the printer, I find that the investigations of Professor Helmholtz have been noticed by Mr. Sorby, in his presidential address to the Royal Microscopical Society.* This gentleman's comment on the "Limit of the Powers of the Microscope" bears mainly upon the conclusions of Professor Helmholtz respecting the influence of diffraction upon the image, formed in the microscope, of very fine and closely ruled lines, and on the limit thereby placed to their separate recognition by the eye. A formula, expressing the physical limits of resolution—*i.e.* the measure of narrowest interspace between two finely drawn lines which admits of the formation of a separate and distinct image of these lines upon the retina—was deduced by Helmholtz, from his mathematical demonstration of the theory of diffraction, as it occurs in the microscope. Mr. Sorby, quoting this formula, employs it for a few calculations, arranged in tabular form, showing the limits of resolution of a series of lines, when

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* *Vide Monthly Microscopical Journal*, number for March, 1876.

viewed through a microscope armed with objectives of given angular aperture, under the several conditions of illumination by red, blue, and mean rays of the spectrum. Of course this formula, and all calculations made from it, must exceed any possible actual performance, even on the assumption of perfect construction of lenses and exact fulfilment of the conditions necessary to perfect amplification, definition, and brightness of image. Helmholtz does not apply his formula to measure *distinctness of definition* of points, lines, spaces, or surfaces, but simply to find how closely two lines (or a series of lines) may be approximated before "interference" waves blot out the separate impression of these lines on the retina, and to mark this nearest approach as the measure of extreme limit of resolution.

But Mr. Sorby, in referring to his table, says :—"The examination of this table will clearly show the value of aperture in 'defining' lines at very small intervals on flat objects like diatomaceæ, though in practice the advantage may be entirely counterbalanced by other (?) disadvantages in the case of a different class of objects."

The readers of Professor Helmholtz's essay will scarcely acquiesce in the correctness of a statement which attributes increase of "definition" to larger angular aperture, unless the term "definition" be understood in a more liberal than literal sense, as meaning *freedom from diffraction effects.* But it must be borne in mind that diffraction phenomena in the microscope arise from two distinct sources, and affect the microscope image in two very different ways. The diffraction which is occasioned when a brightly illumined image is viewed through a small optical aperture (and such is the case in the microscope) annuls, by interference of wave undulations, the vision of very minute objects, or produces false images by distortion. There is here no question of "definition," but of seeing or not seeing, and, *if seen*, of true or false representation. It is a question of "resolving" or not "resolving" the object. The second mode in which diffraction affects the microscope image is when, from some peculiarity in the object, e.g., structural particles or finely ruled lines, &c., some illuminating rays are split into small divergent diffraction pencils, which, entering a wide angled objective, form "positive" images (with, perhaps, coloured fringes) of the particles or lines which caused the diffraction. These images are "positive" because they repeat the self-luminous character which marks their peculiar mode of origin. But, though delineated in accordance with dioptric law, they differ from the "negative" images formed by non-diffracted rays (that is to say, by the ordinary pencils of light) in one important respect, namely, that, owing to the greater dispersion of such diffracted pencils before reaching the objective, a large aperture only can admit them, and the diffracted pencils which form these positive images have, therefore, a greater inclination to the axis.

If now "definition" be interpreted to mean accurate geometric delineation of a microscope image, it is manifest that the source of "definition" is *not* "angular aperture" of an objective, but accurate *focussing function* of a lens or system of lenses. And, so far as concerns the diffraction images admitted in virtue of large aperture, they may be a cause of *deterioration* of the general effect, unless the spherical aberration of rays having an extreme inclination to the axis of the instrument, be so corrected that the focussing function shall bring the diffraction images into perfect correspondence with the negative images formed at the same moment. And again, as respects the diffraction effect caused by the minuteness of optical aperture of the whole system of lenses of the compound microscope (including the ocular), through which the final image is viewed by the eye, the good effect of large "aperture" of objective is also *contingent* upon the perfection of its focussing function, that is to say, *depends upon good definition instead of being the cause of it.*

The view here briefly expressed accords strictly with the observations of Professor Helmholtz, and the researches of Professor Abbe, and I propose, as the subject is not without interest at the present moment, to discuss it a little more fully in the following pages.

In the first place Helmholtz has himself, in the first part of his essay, indicated the true nature of definition by showing its dependence on the aperture, *not* of the objective, but of the illuminating cone of light beneath the object. The angular divergence of the pencils issuing from the object and incident upon the objective being regulated by that of the illuminating cone, every one who uses a diaphragm between the mirror of his instrument and the object on its stage (or any arrangement employed for the same purpose) practically recognises and acts upon the fact (whether understood or not) that delineation of the microscope image is best regulated by comparative trial of the different sized openings in the diaphragm. Or, in other words, by suiting the angular divergence of the defining pencils—it is the light which defines—to the capacity of the lens used. And a very little experience suffices to show that the effect of a larger or smaller illuminating cone stands in direct relation with the magnifying power used. With low and moderate powers, the best "absorption" or "negative" image is obtained by using the diaphragm to shut off light, *i.e.* by *reducing* the divergence of the defining pencils, which thus enter the objective with less inclination to the axis and form sharp points instead of "dispersion circles." With higher and highest powers the divergence of defining pencils may be extended until nearly the full aperture of the objective is occupied, but definition becomes more and more critical. In the first half of Helmholtz's essay the relation of illuminating cone to amplification and brightness of image is fully demonstrated, and it is shown that no diffraction effects occur until the optical aperture through which the image is viewed becomes smaller than the aperture of the pupil, but that they increase at an enormous rate as the magnifying power is increased.

In the next place Professor Helmholtz, in dealing with the question of extreme limits of resolution, obtains from his theory of diffraction the formula $\varepsilon = \frac{\lambda_0}{2 \sin \alpha}$. He does not, however, apply it as expressing any value of "defining" power of aperture, but simply as *expressing a certain relation between the wave length of the different colors of the spectrum, and the aperture of an objective* by which the smallest interspace between finely drawn lines which shall allow these lines to be separately visible to the eye may be computed.*

And he himself gives the following arithmetical calculation in accordance with his formula:—Taking ·00055 mm. (= $\frac{1}{1818}$ mm.) as the wave length of medium rays, and 90° as angular divergence of a dry lens (or a lens constructed on immersion principle used dry), and assuming perfect correction and adjustment of lens and instrument, then $\frac{1}{1818} \div 2 = \frac{1}{3636}$ mm. (or $\frac{1}{92000}$ inch).

This is the same calculation and gives the same result as that in Mr. Sorby's table for mean rays and 180° aperture (twice the divergence angle).

Helmholtz next points out that if the rays could be transmitted through water with the same divergence as through air, then the wave length λ would be $\cdot 00055 \times \frac{3}{4} = \cdot 0004125 = \frac{1}{2442}$ mm. And a being supposed = 90°, it follows that $\varepsilon = \frac{1}{2424} \div 2 = \frac{1}{4848}$ mm. or $\frac{1}{122000}$ inch.

The extreme limit of minuteness is then shown to be *dependent on the wave length of illuminating rays.* And this appears more distinctly from the calculation when blue rays are employed whose wave length $= \cdot 0004282$, as ε is then $= \frac{1}{4670}$ mm. or $\frac{1}{118000}$ inch, with the immersion lens *as at present used*.

The figures in Mr. Sorby's table show (what has, however, been long known), firstly, that red light is the worst for rendering minute objects visible, whilst blue, if collected in sufficient quality to supply brightness of image as well as to bear high amplifications, would be best. This inference is, indeed, sufficiently justified by the known differences of susceptibility of the retinal nerves to colour (i.e., for undulations of such widely different wave lengths as those of red and blue), and by the different course of these rays

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* The *same formula* and the *same explanation* of it is given by Professor Abbe, in ¶ xix. of his essay (page 244 this vol.), namely, that it expresses the extreme limit of separable objects—so far as *seeing* is concerned. But this theoretically possible "resolution" becomes an actual one, only when the essential conditions of definition—accurate focussing function and regulated angle of illuminating pencils—are also properly fulfilled.

through the dioptric media of the eye.* But secondly, the table shows that increase of aperture is not so efficient in resolving the extreme minute lines or spaces when the aperture is increased beyond 110° as when it is being raised from a comparatively low figure up to this degree. Neither is "*variation of defining power with the chord of the angle of aperture*" (J. Hogg†) to be understood as one of progressive excellence due to increase of aperture, nor, indeed, is this use of the term *defining power* "in absolute agreement with" any teaching of Helmholtz concerning definition, or with any theory of diffraction phenomena which interfere with the vision of closely ruled lines. This appears even from Mr. Sorby's own table, calculated from the formula given by Helmholtz. For, if the figures in this table (copied from the Monthly Microscopic Journal, for March),

	60°	97°	120°	150°	180°
Red End of Spectrum ...	$\frac{1}{37000}$	$\frac{1}{55000}$	$\frac{1}{64000}$	$\frac{1}{71000}$	$\frac{1}{74000}$
Mean Rays	$\frac{1}{46000}$	$\frac{1}{69000}$	$\frac{1}{80000}$	$\frac{1}{89000}$	$\frac{1}{92000}$
Blue End	$\frac{1}{60000}$	$\frac{1}{90000}$	$\frac{1}{104000}$	$\frac{1}{116000}$	$\frac{1}{120000}$

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* This difference in discrimination of colour by different parts of the retina is a normal one, but is not evident when white light is used because the middle rays greatly predominate. The difference reaches its climax in persons who are colour blind, the commonest form of which is red blindness, when red colour (and the red end of the spectrum) cannot be seen at all. The hypothesis of Dr. Young is accepted by Helmholtz, viz., that one kind of nerve when excited by the longest undulations induces a sensation of red light, a second nerve excited by medium undulations induces green light, and a third nerve excited by the shortest undulations conveys impression of violet. The latest anatomical researches tend to show that a triple strand of this kind forms the rather thick nerve which connects the *cones* with the ganglionic layers of the retina.

† See Mr. Sorby's address (loc. cit.), page 110, line 12.

be compared as they stand in each column, one fraction under the other, they clearly prove that the number of distinguishable lines and interspaces (or, as Mr. Sorby puts it, the number of lines "defined" at very small intervals) *varies as the wave length of the colour* with the *same angle of aperture.* And this would be true of all the colours of the spectrum. Taking the extremes and means as here given, the variation of *what is called* "defining" power is as 1 : 1·63 *for the same aperture.*

Or again, if the fractions in the two columns, headed respectively 97° and 180° (a difference of more than 80°), be compared, we find that the *lens of* 97° *aperture*, with blue rays, "defines"—supposing, with Mr. Sorby, that his table "clearly shews the value of a large aperture in defining"—*as well as the lens of* 180° *aperture* with white light.

But it may perhaps be said that when the figures are read in line instead of column they *do* show increase of defining power with increase of aperture. Yet, on nearer consideration, it will be found that the denominators of the fractions denoting approach to extreme limits of "definition," although rising to a higher figure, actually indicate a diminishing rate of increase. If, for instance, the "defining" power of an objective of 60° aperture be called 1, then the difference of increased "defining" power of an objective of 90° aperture is — compared with the first — as 1·5 : 1. But the rate of defining power of an objective of 120° aperture to that of the objective of 90° is only as 1·16 : 1. And the rate of defining power of an objective of 150° aperture to that of the objective of 120° is only as 1·1125 : 1. Lastly, the ratio of "defining" power of the objective of 180° to that of an objective of 150° is only as 1·0337 : 1. From this it is clear that a few degrees of aperture beyond 110° cannot give any appreciable increase of value *when the effect of a rise of* 30° *at a time is so little.* And this too, in spite of the fact that every 30° of additional aperture, gives a largely increasing zone of marginal light. But, while the figures of this table fail to prove the value of large aperture in "defining," they indicate still less respecting the amount and quality of light admitted by larger aperture, and they ignore a circumstance which really is, and should be considered, the master condition of the problem, namely, accompanying increase of magnifying power, because angular aperture is a necessary accompaniment of the construction by which increase of magnifying power is obtained (increase of curvature and shortening of focal length of the lens). Now the definition of the more magnified image may or may not be improved, but if only *not deteriorated* the additional amplification cannot but further separate and thus render visible (resolve) lines that were too close to be seen separately with a glass of smaller aperture and lower power.

The fractions in the table indicate that separation of detail progresses in a marked manner with increase of angle up to 100° or 110°. And this range of increased aperture corresponds with the deepening curves of construction of a lens by which its magnifying power is raised. But, beyond the amplification suited to an aperture of 110° (in an objective made to be used "dry"), the resolution of lines separated by clear interspaces is obtained with greater difficulty, because the additional magnifying power spreads the light over a larger image, whilst that image must be viewed through a smaller optical aperture. As soon as light and shade are less contrasted, sharpness of vision fails. And, with high power lenses, diffraction effects are unavoidable if the illumination be intense. Thus the limits of physiological vision are being approached in two ways—first, by faintness of marking if the brightness of image fails; and secondly, by indistinctness of outline from overlapping images or blurring by interference waves. The faculty of visual analysis is weakened or destroyed before the theoretical limit (half the wave length of violet rays) is reached.

Now, it is known that definition is improved in all low and moderate amplifications by use of diaphragm openings, which regulate and reduce the angular spread of the incident defining pencils of light. But this narrowing of illuminating pencils necessarily favours diffraction, whilst wide pencils (i.e., larger angles of incidence) moderate diffraction. "Definition," therefore, instead of improving "with the chord of the aperture," depends rather upon a compromise between magnifying power and aperture which shall give the greatest brightness of image, compatible with good focussing function and least diffraction. The first and most important condition under which it is possible to maintain good definition is the counteraction of that spherical aberration which increases with power and aperture of a lens-system, by the proper calculation of curves and refraction of its constituent parts, and compensation for residual aberrations. And the difficulty of construction and compensation is increased with every addition to aperture beyond 110°*.

That the physical limit of resolution, computed from any formula based on such assumed perfection of the microscope as is needed to realise every theoretical possibility, must be in excess of what the eye itself can perform, will be obvious to all who have studied physiological optics. A few observations on this part of the subject will be appended to the present paper, but attention may here be directed to the fact that far more minute details may be delineated in a photograph than on the retina. Undulations of shorter wave length than will affect the retinal nerves can act powerfully upon photograph materials, so that chemical rays delineate lines too closely approximate for the eye to distinguish when looking at the same object through the same objective. Here then the resolution is entirely physical, and the *physiological limit of eye performance is surpassed.* This fact is indeed but an extension of the principle that "resolution" is associated with the different wave length of

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* It is true that lenses of equal magnifying power, but different aperture, perform very unequally, and that definition will often be best in the image formed by the objective of larger angular aperture (excepting cases of extreme angle), provided that correction of spherical aberration be perfect for those parts of the objective through which pencils of large divergence angle pass, so that their points shall not become dispersion circles. But mere aperture, without suitable construction, confers no defining power. In Professor Helmholtz's essay the mathematical demonstration is based on the assumption of a perfectly constructed *immersion* lens, where, as Abbe has conclusively shewn, the correction of spherical aberration is not attended with such difficulties as is the case with large angled "dry" objectives.

different rays of the spectrum, as pointed out already in connection with Mr. Sorby's table. It serves, moreover, to shew that the focussing function by which the photographic picture is delineated must be the really important instrument of definition, for the *amplification* of the microscope-image by chemical rays acting on a photographic plate is *greater* (as 3 : 2) than when seen by the eye*.

But the total inadequacy of the dictum that "defining power varies with the chord of aperture" should appear from the very obvious fact that the definition of a modern camera lens or telescope object-glass is more perfect with less angular aperture than belongs to microscope objectives of even low power. Or, if this dictum be intended to apply only to the microscope image, it remains to be shewn how it may consist with the fact that the objective of say 120° of aperture, made fifteen years ago, does not equal in performance the objective of *same aperture* made now, or with the fact that an immersion lens of smaller angle surpasses the definition of a dry lens of greater aperture; or again, with the fact that lenses having the same angular aperture, but constructed by different makers on different lines—nay, even when made by the same optician, and on the same principles—vary in "defining" power according to the illumination and to the kind of object.

Does not such a dictum (it were not worth while to disprove it but for the prevalence of an error which might be traditionally perpetuated amongst other myths appertaining to the history of the microscope) ignore too much, and take too much for granted? Does it not ignore the defects which excessive aperture introduces? Does it not assume that difficulties of the optician are all solved for him by angular aperture? Has it not driven the optician himself against his better knowledge and experience into a struggle for a few more degrees of aperture, and filled the purchaser with a delusion that an objective is cheap at any price which has these few additional degrees of aperture?

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* See page 245 of this vol., Abbe on the Theory of the Microscope.

A better understanding of the part played by aperture in defining (as distinguished from *resolving*) microscopic objects may be gathered from the essays of Helmholtz and Abbe, translations of which have been given in the preceding pages, than from any misapplication of a formula intended only as a mathematical expression of the possible limits of resolution. The readers of these essays will have seen that to each of these terms, long naturalised in micrography, and supposed to convey a separate and distinct meaning, a specific function answering to specific physical phenomena may be truly assigned. In this, as in other scientific enquiries, all depends on a clear and accurate definition of the terms employed, especially when such terms are intended to convey some explanation of complex phenomena and combined effects. For to such combined effect, the reference made by Mr. Sorby in the passage before quoted from his presidential address, was, doubtless, intended to apply. But it seems a pity to endanger the most instructive results of modern research—the fruit of much profound labour—by any loose application of a single term to cover all the physical phenomena concerned in the formation of a well defined optical image. The foundation of the whole series of phenomena which have to be analysed in a theory of the microscope is that dioptric law governing the focussing and magnifying functions, which obtains equally in every objective whatever be its angular aperture; and "definition" depends alike in small or large angled objectives upon correction of spherical aberration. Increase of angle beyond 110° only throws difficulties in the way of the optician as regards the maintenance of even moderately perfect definition.

For the oblique incidence of the outermost pencils—the prime cause of spherical aberration—is the main characteristic of large aperture. And the possible gain of defining pencils of large divergence angle, as well as the possible addition of new details admitted with diffraction pencils (from the object) through the wide angled aperture, will be realised only in proportion to the dioptric perfection of focussing function. In respect to "resolving" capacity, of which "aperture" may be considered in a certain sense the measure, we have learnt from Helmholtz and Abbe that the deterioration of image, caused by diffraction effects upon the eye looking through a minute optical aperture at a highly amplified image, is lessened by a relatively larger angle of incident defining pencils, and by other circumstances to be mentioned presently. But the formula of Helmholtz, illustrated in Mr. Sorby's table, shews us how greatly the limits of resolution vary with wave length of colour*. The careful study of the optician in producing an "achromatic" objective is so to equilibriate the extreme red and violet images as to give a colourless image in some intermediate focal plane by counteraction of and compensation for aberrant rays. In remedying these defects of dispersion and deviation, as also in perfecting the amplification needful for resolution of minute objects, the operation of angular aperture is *passive* only, whilst the co-operation of every dioptric condition on which their correction depends, must be active. Hence, therefore, the dictum that "defining power varies with chord (!) of aperture," besides leaving everything to be explained, is a most incorrect summary of facts.

When it is considered that the microscope image is literally delineated in points of light from innumerable pencils, each one of which must touch the focal plane at its proper relative distance from the axis around which the image is formed†, it is manifest that

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* And also how greatly chromatic dispersion interferes with clearness of resolution.

† The translation of the fundamental law, formularized by Professor Abbe (see page 211 of this vol.), together with the sentence preceding it, having been incorrectly printed from the MSS., we repeat it here as corrected. "The study of these aperture images leads to various conclusions, the full development of which depends on a principle capable of general demonstration, and which may be formularized as a law applicable to every part of the theory of the microscope in the terms following":—

"*When a system of lenses is perfectly aplanatic for one of its focal planes, every ray proceeding from that focus strikes the plane of its conjugate focus at some point whose linear distance from the axis is equal to the product of the equivalent focal length of the system and the sine of the angle which that ray forms with the axis.*"

On this law of focussing function depends the geometrical delineation of the microscope image, whose amplification is likewise herein indicated as depending on focal length and angular aperture of a lens system.

perfect freedom from spherical aberration must be the first and principal condition of accurate definition, and the existence of dispersion circles in place of pointed pencils constitutes the greatest fault of the image forming process.

The conditions under which every objective, whether of large or small aperture, must perform its focussing function are contained in the law demonstrated by Professors Helmholtz and Abbe. In order to see in what respects definition is improved, or otherwise, by additional aperture, it is necessary to determine in what respects the objective of larger aperture differs in its mode of action from an objective of small angle, and how this mode of action affects the dioptric conditions of the focussing function. Now it appears, 1, that the objective of wide aperture admits larger divergent pencils than the smaller angled lens; 2, that, of these larger pencils, such as occupy the peripheral (marginal) zones of the front lens, have a greater inclination to the axis of the instrument than any pencils incident on the lens of narrow aperture; 3, that these outer zones admit not only larger pencils of light, according to the angle of illuminating cone under the object, but also any rays split up by diffraction due to the action of particles in the object, &c., which fall within reach of the aperture of objective. These three points of difference indicate corresponding differences in the conditions of focussing function in large and small angled objectives respectively. In respect to the first (which has a direct bearing upon the theory of diffraction in the microscope) the differences of divergence-angle of the defining pencils of light which enter the narrow or wide aperture of objective, affect, in directly opposite ways, the definition of the image, and the diffraction effect of this image on the eye. Definition is best with *narrow* pencils *up to a certain point*, namely, that at which the narrow illuminating cone being focussed in the optical aperture above the eye piece becomes so small in relation to the magnified image and to the pupil of the eye that diffraction effects begin to appear. From this point, any increase of intensity of light of the narrow pencils increases diffraction; but larger incidence angles of illuminating pencils moderate diffraction. It is, however, clear that aperture is not *alone* concerned in affecting the minimum of diffraction with maximum definition, since the result depends also upon the relative amplification of image (magnifying power), the size of detail in the object, and the nature of illumination, i.e. kind of light, and whether central or oblique illumination. Nevertheless, *cæteris paribus* wider angle offers a wider range of manipulation and effect to the practised microscopist.

In respect to the second point, the greater inclination of pencils to the axis, the advantage arising therefrom lies chiefly in the power of varying the illumination. The widest cone of light that can enter an objective is that whose point lies on the object exactly in the centre of the axis of the instrument, and whose divergence just fills the available aperture. This cone (above the object) requires that the illuminating cone below the object should be of equal size, and the regulation is best effected for each separate objective by diaphragm and illuminating lens system. Such a mass of light collected equally from all sides must of course yield the utmost quantity that can be obtained, and is, therefore, needed to give brightness to the wide spread image of an object magnified by the highest powers. If there be no chromatic dispersion (which, as well as spherical aberration, is a defect inherent in large aperture), this wide cone of light, entering with relatively wide divergence angle, tends to moderate the diffraction associated with highly magnified images. But, excepting cases of enormous amplification, this absolute maximum of light defines badly, because the bright images formed by pencils passing through every part of the periphery of aperture pour from all sides such a flood of light upon each other as to lessen the delineation by the darker outlines of the absorption (negative) picture. Besides which the general brightness of the field fatigues the retina and also occasions entoptic shadows.

On the other hand, if this central illumination be shut off on one side, or a central stop used with it, a lateral or peripheral illumination with partial or entirely dark field offers the opportunity of observing many useful effects, particularly when "positive" images only are formed. But the more usual form of oblique illumination, by placing the mirror out of axis, tests to a greater extent the advantage of large aperture in all cases where the object to be resolved contains very minute structural elements, especially when arranged in equidistant lines or points placed either in parallel position or at particular angles to each other. The effect of this oblique illumination is directly proportionate to the amount of inclination of image-forming pencils to the axis of the microscope, and, of course, as only one side of the marginal zone of front lens is in operation, and, therefore, fewer images are formed, there is less overlapping and confusion of outlines.

In respect to the third point—the admission of pencils of light diffracted in passing through the object—large aperture is so essential that it may be said to add (or at least to permit) an entirely new function to the objective. According to Professor Abbe the capacity of "resolving" all minute details is dependent upon the formation of "positive" images by the combination of two or more diffraction pencils, caused by structural peculiarities of the object. These diffraction pencils enter the objective in virtue of its large aperture, and form a diffraction image (or positive image) independently of the absorption image (or negative image), which latter is formed according to the dioptric law by which homocentric pencils proceeding from a focal point are re-united in its conjugate focal point.

But neither is the negative nor the positive image formed with large pencils filling the whole front of the lens system. Each passes independently through different zones of the lens, and changes its position as the illumination is changed. Unless they fall together on the same focal plane, and are accurately superimposed, these negative and positive images will appear in front of, or behind, or beside, each other, and, therefore, the "resolving" power does not *necessarily* become additional "defining" power. Again, the definition of each image may not be much deteriorated by faulty focussing function or colour dispersion—when the pencils are not large so that their points do not suffer much dispersion—yet, still the combined effect will be marred in proportion as the object is not uniformly free from spherical aberration over the whole area of aperture.

Again, objectives may be constructed with wide aperture, and the focussing of the most inclined pencils be effected with sufficient accuracy, whilst the central zones are left very deficient and incapable of correction. The "definition" of such objectives will be poor even for the particular class of objects for which wide aperture is needed, whilst their definition for ordinary objects will be worse than in good glasses of narrower aperture. This case is far from rare.

Thus then mere aperture is not decisive of the value of an objective, and the struggle for a few degrees of extra aperture may often prove absolutely injurious to definition. It may, indeed, be possible to correct the defects and surmount all difficulties attendant on the use of largest possible aperture even in dry objectives, but to estimate objectives by mere comparison of their respective apertures is as useless as to deny, on the same grounds, the proved excellence of objectives of moderate aperture (100°) which can and do combine resolving and defining capacity commensurate with high magnifying power. Lastly, it appears that the highest resolving power associated with largest aperture is of value only for a special class of objects, namely, such as consist of finely ruled artificial lines, networks with transparent interspaces, or such as contain in their substance, otherwise homogeneous and transparent, minute particles of differing refractive power which cause diffraction. But all such objects, when employed as *tests* for resolving power, fail to exhibit the general and more useful qualities of objectives constructed to define as accurately as may be in one picture (with each fresh focal adjustment) elements of variously irregular figure and light-absorbing power situate in focal planes of varying depths where a resolving capacity of $\frac{1}{80000}$ inch would not penetrate. Even in the case of particles held in suspension in a more or less transparent fluid, the best combination of resolving and defining capacity would avail far more than extreme resolving power which might suggest some indefinable reality.

On the Physiological Limits of Microscopic Vision.

By DR. FRIPP.

THERE is yet another aspect of this subject which, though seldom studied in connection with the microscope, is of more significance in estimating the limits of vision than lens aperture; namely, the dioptric performance of the eye, and the capacity of the retina to receive and transmit impressions of light.

In Mr. Sorby's address, to which reference has been made in the preceding pages, the " physiological part of the question " is dismissed in a sentence because Mr. Sorby " does not believe *that the ultimate limit of distinct vision would be found to depend on the constitution of the eye.*" And he seems the more confirmed in this opinion by the inference which he draws from certain experiments made by Dr. Pigott that " *the eye could distinguish with a high magnifying power a much smaller interval than the physical properties of light will permit.*" Mr. Sorby further adds (in reference to Dr. Pigott's estimate of $\frac{1}{1500000}$ to $\frac{1}{2000000}$ of an inch as the limit of visibility,) " *This (?), however, is not what appears to be the most important character of light in limiting the power of the* *microscope for separating lines so near together that they may be obscured, or their number falsified, by interference fringes.*"

The "*physiological part of the question*" has, nevertheless, been always considered by astronomers, mathematicians, and physiologists to be an essential part of the theory of vision, whether by the naked eye, or with the aid of optical instruments. All that relates to the distinguishing power of the eye, all that we know of magnifying power, all our outward experiences of light, colour, form, size, distance, direction, proportion, and perspective are gained through the sense of sight. And it is impossible to understand the physical characters of light without considering how far they are dependent upon and related to the action of the instrument through which we become acquainted with them. I confess myself unable to comprehend to what "important character of light," allusion is made by Mr. Sorby, as "limiting the power of the microscope for separating lines," &c. If it is merely intended to convey the idea that the effects of diffraction tend to limit the power of the microscope before the full advantages of magnifying power are obtained, the question certainly merits full consideration, and indeed has been already fully discussed in the papers of Helmholtz and Abbe.

But if it be thereby meant that the eye can distinguish the three-millionth of an inch, or the $\frac{1}{3000000}$, or even $\frac{1}{1500000}$, of an inch with the microscope, *because* when, unarmed, the eye "distinctly appreciates" a visual angle of six seconds, and that consequently when aided by high magnifying power the "constitution of the eye" renders it capable of a *defining* power which is only limited by the intervention of certain "physical characters of light," such an inference can, as it seems to me, only be arrived at by ignoring entirely the study of the dioptrics of the eye. For in the eye, as an optical apparatus, the distinction between *acuteness* of vision and *clearness* of vision covers the same ground as the discussion of "resolving" and "defining" powers of an artificial lens-system. Spherical aberration and chromatic dispersion are alike concerned in the image-forming process of eye and microscope. But the dioptric function of the eye is further impeded by circumstances which do not occur, or if they occur can be better remedied in the achromatic lens-combination of the optician. For instance, animal tissues and fluids are inferior in translucency, homogeneity, refracting, and dispersing power to the materials of which an objective is made; opaque particles fixed or floating in the eye-structures occasion shadows; diffraction spectra of the crystalline lens and shadows of the retinal blood vessels obscure the field of vision. And these difficulties which, as will be shewn in the following pages, are neither few nor unimportant, are inherent in the constitution of the eye; whilst the only circumstances which favour the accuracy of images are (first), that the plan of anatomical construction admits of accommodation of lens to varying focal distance and of movement of the eye on its axes; (secondly), that the eye reduces the image instead of magnifying.

We may, in the first place, consider the question of visual angles and magnitudes. Mr. Sorby quotes an experiment of Dr. Pigott's, by which this gentleman determined a datum of six seconds, from which a magnifying power is inferred when a microscope of $\frac{1000}{1}$ power is used, and this magnifying power is considered as indicating what the distinguishing power of the retina might be if not obstructed by diffractive effects.

Now, assuming the physiological value of the acuteness of vision to be an angular distance, it should not be forgotten that this smallest angle is *determined by the illumination.* "To illuminated points on a dark ground there are scarcely any boundaries. Small as such a point may be, its image has, on account of the *imperfection of the dioptric system of the eye*, a certain extent; and the only question is whether this produces on one or more percipient elements of the retina a sufficiently distinct impression of light to be perceived. Small dark points disappear, on the contrary, very rapidly through irradiation on a bright ground, which lessens the contrast of illumination of percipient elements, and, if the illumination be strong, the contrast will be much less perceptible. The question as to the smallest angle under which any object is still to be seen is thus *governed completely by the degree of illumination*, and in a physiological point of view it has, therefore, no meaning. *It is a very different thing to determine the influence of illumination on the indistinctness of objects.* Nor is the investigation with a definite illumination devoid of importance in a practical point of view (microscopical investigation), from which view Harting especially has worked it."*

The facts quoted in the note conclusively show the inutility of attempting to determine "limits of visibility" by calculation

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* See *Donders* on Anomalies of Accommodation and Refraction of the Eye, translated for Sydenham Society by Dr. Moore, 1864, page 195.

Dr. Pigott's estimation of visual angle (for his own eye) is cited without any explanation of the various conditions which affect such observations. The experiments of Hueck show:—1. That a normal eye, capable of accommodating itself to near and distinct objects, finds small objects, whether near or far off, disappear at the same visual angle. (N.B.—The comparison being made under same conditions of illumination and by the same eye). 2. That a *line* is seen further off than a *point*, though both may have the same thickness. 3. *White* objects on a *dark* ground are seen at a greater distance than *black* objects on *white* ground. 4. At great distances the necessary visual angle for recognition of objects slightly and gradually increases. 5. The smallest visual angle at which white *points* on black ground were visible was 2′·6, whilst white *lines* on black ground were seen with an angle of 1′·2. A cobweb thread with an angle of 0′·6, and a white hot wire at 0′·2.

Volkmann found that he could distinctly see a hair ·002′ diameter placed 30″ distance. This gave ·000033 inch for the dimension of its retinal image according to his calculations. But he considered such observations unsuited to determine the size of the smallest retinal images which could excite the sensation of vision, firstly, because dispersion of light (from spherical aberration of the crystalline lens) might affect a larger retinal surface than would correspond to the calculated dimensions of the image; and secondly, because irradiation of the stimulus of light would likewise spread beyond the precise area to which that stimulus was applied. And the following experiment appears to shew that one at least of these two circumstances really occurs:—Two parallel cobweb threads being set up with an interspace between them of 0·0052″, Volkmann recognised them as double threads at 7″ distance but not further. But a friend who possessed acuter vision recognised the double threads at 13″ distance. The dimensions of the respective retinal images Volkmann calculated, for his own short-sighted eye, at 0·00037″, and for that of his friend at 0·00021″. But by another experiment (two threads 0·016″ apart, seen at 27″ with aid of spectacles) Volkmann determined the dimension of retinal image, appreciable by his own eye, at 0.00029″. From a comparison of the figures in the two experiments he concludes that the smallest magnitude which his eye could recognise was ten times greater than the smallest recognisable retinal image, and that the focus which his eye could form at suitable distance of vision occupied a space of 0·00029″, and lastly, that the reason why he could not see an object under any minuter visual angle was because the light would then be too much dispersed.

from visual angles of minute obj s. For we see that even in normal vision with the naked eye t retinal images are falsified by dispersion of the light passing thr gh the eye structures, and by indistinctness of retinal percepti , consequent upon defective delineation of image and insuffici contrast of light and shadow. But if little value can be placed calculations of actual, from apparent, magnitudes of the visual agles of minute objects, what is to be thought of the assumption at a visual angle, obtained by observing an object with the naked e and under normal conditions of vision, can be made the basis f calculation of a magnitude obtained by looking through a mic cope magnifying 1000 times, without supposing the calculation o be affected by the widely altered conditions of vision, and y a wholly different mode of illumination? Even the magnifyi power taken for granted as due to the microscope, (say $\frac{1000}{1}$), i *compound effect* of the eye and the instrument, the retinal image ng about 16 times less than the image presented to the eye supposed to be seen at the "distance of clear vision" (10 inch). And we have already seen that acuteness of vision does not pend upon magnifying power further than is necessary to separ two objects from each other sufficiently to be capable of givin eparate impressions, and this distance is clearly governed by th *distinguishing capacity of the retina.* So again distinctness of i ge is dependent on accurate dioptric function of the eye equal with that of the microscope. Lastly, in regard to diffraction, w h indeed has been proved to exert a potent influence on the mi cope image *as seen by the eye,* it must be borne in mind that thi iffraction is not produced by any faulty quality of a lens-system ut is the simple consequence of the optical arrangement neces to bring an enlarged image before the eye, because such a ngement necessarily implies "angular amplification," whereb he whole mass of light, by which the image is delineated, is sented to the eye in a concentrated form, and reduced secti l area, in front of the pupil. Professors Helmholtz and Abbe ha insisted on the circumstance that diffraction in the microscop caused by the narrowness of opening through which a strong light is viewed, the effect being the same whether produced by a pin hole in a card or by a minute optical aperture of very highly magnifying lenses, combined or not with deep oculars. The diffraction then which limits the resolution of objects in the microscope is a physiological effect attendant upon conditions which do not occur in the ordinary use of the eye, but which, whenever they do occur, are the source of obstruction not to the performance of the microscope, but to the function of vision. For it is evident that a phenomenon which is as readily produced by a pin hole in a card, or by various other physical means, as by looking through a microscope, cannot be attributed to faulty "definition" or "colour dispersion" of this instrument, but that it appertains to the general conditions of vision exercised under circumstances unfavourable to the dioptric performance of the eye as an optical instrument. Whatever, therefore, may be the limit of its performance, it must be sought in the retina or in the dioptric media of the eye. Supposing the microscope picture to be well delineated by a lens of as perfect construction as can be made, the delineating pencils of light which pass out of the microscope in a concentrated bundle of intensely bright rays would, if thrown upon a sensitive chemical preparation, form a well resolved image. But if thrown upon the front of the eye, this bundle of image-forming rays has to undergo a fresh series of refractions and reflections, and the assumption that nothing is thereby changed is not consonant with our present experience. We are not justified in assuming that the eye as an optical instrument does, or does not, deteriorate the performance of the microscope (separately considered), or that, on the other hand, the eye, armed with the microscope, would be capable of greatly superior performance but for restricting conditions placed thereon by certain physical qualities of light. For we must not forget that light itself is but a sensation of the eye, and the physical qualities of light but arbitrary expressions of particular effects which ether-undulations produce on the organ of sight. And it certainly appears most conformable with physiological fact and law, to believe that the sense of sight is neither more nor less subtle than the distinguishing capacity of the retina, where the conversion of physical impression into special sensation takes place; and that the capacity of the retina for transferring its sensations (or, perhaps, still only modified physical impressions) to the brain, stands in exact proportion to the subtlety of impression which it has received through the separate elements of the retinal layer of *rods* and *cones*. Further, we should expect to find that the dioptric performance of the structures of the eye in front of the retina was just as accurately adapted to the capacity of the retina for receiving separate impressions, yet not beyond it. But, as there appears no *a priori* reason why the sense of sight should exceed in potential subtlety the limits of any possible act of seeing, or the capacity of the apparatus on which the sense depends, so there seems no ground to attribute the limit of visibility to any antagonistic "physical character of light." If we suppose a dioptric apparatus to be perfect in its capacity of transferring isolated pencils of light, giving separate impressions from each illuminated point in an object, the limit of vision *for that object* will be measured by the visual magnitude of interspace between the illuminated points, provided that interspace does not exceed or fall short of the measure of the percipient element on which each single impression falls. Therefore the finer the percipient element and their interspaces, the finer may be the delineation of detail belonging to an object which detail shall yet be distinctly seen. But microscope objects generally (and some in particular, *e.g.*, closely ruled lines) which cannot be distinguished by the naked eye because their retinal images (16 times smaller) can have no appreciable dimensions, may be rendered visible with the help of such amplification as will spread their detail, *e.g.*, lines and interspaces, so as to fall singly upon the percipient retinal elements. And, so far, magnifying power is *necessary* for vision of minute objects, in order that the images of their structural details may correspond with the dimensions of the percipient elements. But each object so magnified should receive its due illumination in order that the impression of each detail on the retina may fall with sufficient intensity, as well as on the right place, *e.g.*, microscopic intervals between ruled lines together with the lines themselves must be rendered visible by contrast of light and shade, as well as by equalisation of their scale of size with the dimensions of the retinal percipient elements. Hence the necessary relation between magnifying power and aperture of a microscope objective. But supposing in the next place that there should arise with the fulfilment of these conditions a new difficulty—and the case does so arise—that, namely, of diffraction, are we to interpret it as a failure of the microscope or of the eye? In considering this question the following facts must be kept in mind :—1. There are two distinct sources of diffraction. When points in an *object* become self-luminous by the diffraction *occasioned in the object*, so much detail is added to the picture by a wide angled objective which takes in such diffracted rays and re-produces by its focussing function the image of the diffracting particles. Such diffraction is, therefore, a source of gain for which the microscope is to be credited. 2. The second diffraction effect has been already explained as the necessary consequence of the reduction of the microscope image into a bundle of bright pencils entering through the pupil of the eye, and as has also been explained, the evil results of this condition are attributable to excessive angular amplification, but not to faulty lens-construction. The eye is not constructed to work with such abnormal conditions, and vision is, therefore, impaired physiologically. 3. As a matter of fact the modern microscope lens-combinations work so well that undulations of shorter wave length than those which excite sensations of light define (without shewing "interference") finer lines and interspaces on a photograph surface than have ever been seen by the eye, looking at the same object through the same lens-system and under the same illumination. That is to say the retina is not so sensitive as photograph paper, and the dioptric media of the eye cannot transfer the microscope image so perfectly as it can be thrown directly on the chemically prepared paper through the microscope.

Thus then it is plain that resolution of minute objects is not limited by characters of physical light but by physiological in-capacity of the eye to perceive distinctly the objective images of minute structural details under conditions of illumination which are not suited to the distinguishing power of the retina. The constitution of the eye is, in short, the master condition which fixes the limit of resolving or defining powers.

Let us now consider the possible performance of the retina as measured by the actual dimensions and position of the percipient elements. The *cones* of the bacillary layer of the retina at its most sensitive spot (the *macula lutea)* have a diameter at their base (where the focal points of the image fall) of about $\frac{1}{8000}$ inch, and the distance between their centres is about $\frac{1}{6300}$ inch. The *rods* which are not found at the yellow spot, but which everywhere else are crowded closely together, have a diameter of about $\frac{1}{12500}$ inch, and the distance between their centres is nearly the same—say $\frac{1}{12000}$ inch.

The dimensions of the retinal image of an object subtending a visual angle of 60 seconds is $\frac{1}{5770}$ inch.

To show the relation of these figures to each other the following extract from Donders will be useful :—

"The first exact appreciation of the physiological question, we find in Hook's essay on Distinct and Indistinct Vision (1738). He investigates the angular distance required to observe two fixed stars separately, and he found that among one hundred persons scarcely one is in a position to distinguish the two stars when the apparent distance is less than 60 seconds. Subsequently similar investigations were carried on by Mayer, and in our own time by Volkmann, Harting, Weber, Bergmann, and Helmholtz, for the most part with parallel lines or gauge net. It is evident that, for two minute points of light to be seen separately, the centres of their images *must lie further apart from one another than the breadth of a percipient element of the retina* (about one and a half times). If the centres fall at both sides precisely on the boundaries of the same element, this element alone will then receive as much light as the two adjoining elements between which it is situate ; while, in order to see two separate points, a less illuminated space must remain between them. In using stripes and wires, not only the interspaces, but also the thickness of the stripes or wires come under consideration, and in the calculation Helmholtz has, therefore, assumed the angle corresponding to the sum of a line and an interspace—that is, to the distances of the central points of the two adjoining objects. The retinal *elements* must then, at least, *be less* than the retinal *images* corresponding to this angle. Harting and Bergmann have some measurements in which the angle thus calculated is less than 60 seconds. Almost invariably, however, it amounts to from 60 to 90 seconds. By using extremely thin cobweb filaments, the angle in Harting's experiments proved much greater (2 to 3′) than when metallic gauze with thicker filaments was employed. To this cause, no doubt, it is also to be attributed that Volkmann, who made use of cobweb filaments, found particularly high values." (See article in note to page 460).

The dimensions of the *cones* of the retina are, as above quoted, $\frac{1}{8000}$ inch for their thickness, and $\frac{1}{6300}$ inch for their distance from centre to centre as they stand closely crowded together at the "yellow spot" on the axis of vision. But outside of this axial spot the diameter of the cones increases up to about $\frac{1}{4000}$ inch, and towards the equator of the eye are separate from each other by a still wider interspace of $\frac{1}{3200}$ to $\frac{1}{2600}$ inch. This interspace is entirely occupied by the *rod* elements, whose thickness is about $\frac{1}{12500}$ inch, and their distance from centre to centre about $\frac{1}{12000}$ inch. (See figures 1, 2, 3).

View of the Surface of the Layer of Rods and Cones on which the Retinal Image is formed, magnified about 500 *times.*

Fig. 1.—Cones of the yellow spot.
Fig. 2.—Cones on the outer margin of the yellow spot with intervening rods.
Fig. 3.—Cones and rods in the equatorial region of the eye.

FIG. 1.

FIG. 2.

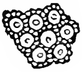
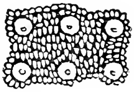


FIG. 3.



How important such an arrangement is for microscope vision may be gathered from the following calculations, it being admitted that the conversion of luminous waves into nerve movement, which constitutes the first step in the act of seeing, really does take place in these elements:—

Let us suppose an object to contain lines or particles distant from each other by the $\frac{1}{100000}$ part of an inch, and that we desire to know the requisite magnifying power which shall bring the retinal images of these lines up to such dimensions as would enable them to be distinctly formed on the retina so that the lines or particles shall be perceived separately by the *cones.* Now an amplification of $\frac{1000}{1}$ should increase the distance between the lines so that in the microscope image they would be situate $\frac{1}{100}$ of an inch apart, and their retinal image would then shew them $\frac{1}{1600}$ inch apart. This would nearly cover four cones, having a distance of $\frac{1}{6300}$ inch apart, *i.e.*, the amplification of $\frac{1000}{1}$ would be unnecessarily high for a retinal image *thrown on the axial yellow spot.* But an amplification of $\frac{250}{1}$ would, by a like calculation, give a retinal image in which the particles would stand $\frac{1}{6400}$ inch apart, and as this corresponds with the actual distance between the centres of the *finest* cones ($\frac{1}{6300}$), the *amplification necessary* to see lines distant from each other by $\frac{1}{100000}$ inch is only $\frac{250}{1}$ times. This proves conclusively that *the difficulty of resolving lines at* 100000 *to the inch depends upon other circumstances than magnifying power*, and points to the defect of illumination and defining power.

But, further, the retinal image of an object subtending a visual angle of 60 seconds is 0.00438 m.m. (Donders), which, converted into a fraction of an inch, is $\frac{1}{5840}$; and this again corresponds nearly with the limit of distinguishing power of the finest retinal cones, as above given, $\frac{1}{6300}$ inch. That is to say *the retina does not distinctly appreciate any closer interval than that given by an object subtending a visual angle of* 60 *seconds or a few seconds less.*

The question naturally follows—if a higher magnifying power be used does it confuse retinal perception by spreading the retinal image of a line a point over several cones? The answer is *not if* *the retinal image is well defined* and its points not blurred by dispersion circles. And the reason of this will appear on further consideration of the anatomical distribution of the cones as they lie further from the axial centre of the yellow spot. Just at this centre nothing but closely packed cones is found, and, therefore, *acuteness of vision is here greatest, reaching its utmost limit of resolving power.*

"The arrangement of the cones at the yellow spot is surprisingly regular. They are disposed in curved lines which converge towards the centre and produce the appearance of shagreen or that produced by the engine-turned back of our watches. This arrangement, which on physiological grounds had been predicted by Hensen, is perfectly regular, the cones successively diminishing in diameter from the periphery of the yellow spot to the margin of the forea."*

Outside the centre the distance between the cones gradually increases. At first each cone is surrounded by a ring of *rod* elements, then by a double and triple row successively, until, as the figures above given show, the distance between their centres increase to $\frac{1}{3200}$, and at the equatorial regions to $\frac{1}{2600}$ inch in place of the $\frac{1}{6300}$ inch at the centre of the yellow spot. From this it follows that a magnifying power of $\frac{500}{1}$ which will form a retinal image of $\frac{1}{3200}$ inch dimensions from an object having an actual dimension of $\frac{1}{100000}$ inch will, *if this image fall upon part of the retina outside the yellow spot*, just fulfil the conditions of separate and distinct appreciation by the retinal cones, and a power of $\frac{800}{1}$ will not separate the lines or particles by a greater distance than that which separates the cones of the equatorial region. This corresponds with actual experience in the use of the microscope. For, according to Helmholtz, Abbe, Harting, Dippel, and others, the highest *serviceable* power for resolving difficult tests does not exceed 500 to 800. And it has been already pointed out that with such high powers diffraction and

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* Max Schultze, Sydenham Society's Edition of Stricker's Histology, vol. 3, page 282.

illumination are the real difficulties to be overcome. It is not, therefore, without reason that Helmholtz has so strongly emphasized the part played by the *photometric relations of light* in the use of high powers, and proved how rapidly the brightness of image falls off as amplification is increased; or, that Abbe has insisted upon the importance of perfecting objectives of medium power instead of seeking to obtain enormous amplifications and employing deep eye-pieces.

In regard to the fact that a highly magnified image must, physiologically, involve the employment of portions of the retina outside the direct axis of vision, it is to be observed that the slightest movement of the eye on its axes will suffice to throw the image upon any required part of the retinal surface round the axial centre, and that this act is constantly being performed in the ordinary use of the eye when attention is directed to such lateral images.

It is also worthy of notice that the *rods* which intervene between the *cones* being equally percipient elements must have their special uses. The thickness of these *rods* ($\frac{1}{20000}$ to $\frac{1}{25000}$ inch) is so much less than that of the *cones* that their function can scarcely be supposed to be that of perceiving *form or magnitude.* But, as percipient elements greatly outnumbering the cones, an important appreciation of the varying amount of light and shade by which the delineation of form is sustained, and by which the pictorial effect of the microscope is distinguished, may with great probability be attributed to their action.

In the foregoing observations the physiological conditions of microscope vision have, it is hoped, been made clearer by placing them upon an anatomical basis which, though as yet still far from perfect, indicates at least an actual and natural foundation upon which to build a theory of vision. A very brief reference to the dioptric function of the eye will suffice to shew how greatly microscopic vision is affected by its special excellences and peculiar defects as an optical instrument.

Supposing every outline, surface, prominence, and depression of an object to be accurately represented in the optical image produced by the microscope, this image must next be transferred through and by means of the eye structures, to the focal plane of the bacillary layer of *rods* and *cones* situate at the back of the retina. In the next place the retinal image must represent the microscope image by exact quantitative differences of white light, supposing the object to be colourless, or if the object contains colour, by an exact counterfeit of the coloured microscope image. By quantitative differences of white light is meant the gradation from white to less white and so on to black (by absorption of white light), and the coloured image must necessarily reproduce as many colours and as many gradations of each colour as exist in the object. But the healthiest and most normal eye cannot accomplish all this without loss of light or deduction from accuracy of definition. There are defects in the physical transmission of the image arising from spherical aberration and chromatic dispersion of the eye, as well as from material obstruction to the direct passage of rays of light. The cornea, for instance, has a curvature which differs in the vertical as compared with the horizontal direction, and its substance is far from being perfectly translucent. Then the crystalline lens contains within its substance six diverging planes formed by the abutment against each other of the ends of the cell fibres of which the lens is composed. These planes, whether actual fissures filled with granular cement, or boundary lines formed by simple end to end abutment of the cell membrane of the fibres, cause a break of continuity and homogeneity of substance, and the consequence of this arrangement is that bright points seen at a distance appear with a halo of rays, the images of the radiating structure of the lens. The general substance of the lens is also, like that of the cornea, sufficiently milky to affect the passage of light through it, and all these effects increase with *age*. As respects the retina itself a far more deteriorating effect than is commonly supposed to be possible actually occurs in every healthy normal eye. This is described by Max Schultze in the following terms*:—

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* Zeitschrift für wissenschaft: Zoologie, Band 8, p 91. See Stricker's "Human and Comparative Histology," Sydenham Edition, vol. 3, p. 288.

"We, however, habitually see through another yellow screen, present throughout the whole extent of the retina, namely, the narrow-meshed plexus of its capillary vessels which lies in front of all the percipient elements. The quantity of the rays of the spectrum, which a single layer of corpuscles, sometimes standing on their edges and disposed like rouleaux of coin, absorbs, is very considerable, as an examination with Browning's spectroscope shows. The hœmoglobin lines are visible, and a considerable portion of the rays at the violet end of the spectrum are lost. With thicker layers of blood corpuscles, like those circulating in the larger retinal vessels, the absorption effects would clearly be much more considerable. Alterations in the blood affecting this absorption power for certain luminous rays, must, necessarily, lead to unusual perceptions of colour."*

And, here, another peculiarity of the retinal structure requires notice. Nearly in the axis of vision, and at some distance to the side of the optic nerve entrance, an intensely yellow pigment is deposited between the elements of the different layers of the retina. The centre of the "yellow spot" is depressed on the surface looking towards the front of the eye, to form the forea centralis. This colouring matter, most intense in the fossa, is completely hyaline, and only so far disturbs the transparency of the retina at this part, that it absorbs a considerable portion of the violet and blue rays before these reach the layer of cones. With the aid of Browning's spectroscope Max. Schultze has distinctly perceived the shortening at the violet end of the spectrum under the microscope.†

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* An important fact must not be omitted, namely, that there *are no retinal blood vessels in front of the yellow spot.* The significance of this fact is two-fold, since there can be no entopic shadows thrown on this most sensitive part of the retina by blood vessels or contained blood, whilst their absence at this spot implies, that the deterioration of vision caused by such shadows really does happen over those parts of the surface, outside the axis of vision, on which images may be thrown.

† The yellow spot is less sensitive to weak light than other parts of the retina. It has been long known that many stars of inferior magnitude are seen more brightly if looked at somewhat obliquely, than when their rays fall full upon the eye. This can be proved to depend partly on the yellow color of the yellow spot, which weakens blue more than other rays. It may also be partly the result of the absence of vessels at this yellow spot, in consequence of which the direct contact with life-giving blood fails.

Lastly, in every eye there exist, either in the vitreous humour, lens, (with its capsule) or cornea, particles which, though not ordinarily seen in looking at objects with the naked eye and with natural daylight, intervene with the effect of shadows throwing opacities whenever a bright light (such as the microscope image with lamplight) is poured through the pupillary aperture.

The defects hitherto noticed appertain to every healthy eye, and are inherent in the histologic constitution of the structures forming the optical apparatus of the eye. That they do not, strikingly, impair the excellence of vision, *as ordinarily exercised by the naked eye,* under suitable conditions of daylight and favourable position of objects seen, is because their ill effects are partly remedied by other circumstances. But it is just when the natural conditions of vision, accommodation of the eye, and muscular movements directed by the mental perception, are most interfered with and strained, — namely, during observation of objects through the microscope—that *every natural defect is exaggerated by the abnormal conditions of vision thus brought about.* The necessity of directing the "mind's eye" to images formed on parts of the retina outside the central axis of vision (*i.e.*, the act of looking sidewards,) has been already pointed out in connection with the anatomical disposition of the *rods* and *cones* of the retina which controls its distinguishing power for coarser details or for more amplified images of finer details. This action is however but part of the whole scheme on which depends the transmission of a microscope image, when physically defined on the retina, to the sensory centres: namely on the susceptibility of the normal and healthy percipient elements to subtle differences of light and shade, (*i.e.*, maxima and minima of intensity of æther undulations,) either as undecomposed white light, or as decomposed into separate colors. In the same object the extreme range from positive to negative, both of white light and of colors, as well as differences of surface from those of least magnitude to those of relatively large areas, may present themselves. Now even under the most favorable conditions of light and shade (daylight illumination,) and of definition (normal use of the unarmed eye,) contrast of outline, coloring, relative light and shade, (as in looking at a landscape) is recognised mainly by a *mental comparison rapidly effected by quick alternate direction of the axis of vision* towards one boundary or another, from one surface to its next contiguous surface, and so on. And this mode of using the eye, long continued discipline of mental vision alone can teach, until finally the inexactitude of the actual retinal images is so compensated and rectified by experience that the adult eye rarely fails of a correct conclusion. The mental vision thus taught and exercised is so different from the retinal impressions (because every imperfect or unnecessary impression is discarded by the mind,) that people *believe what they see simply because they see what they believe.* Now the same training is needed for vision through the microscope. With the monocular instrument sharpness of impression and of direction predominates, whilst the peculiar advantages of vision with two eyes are lost. With the binocular these advantages are regained, but the picture is a composite one with strong perspective effects, though the capacity of appreciating linear direction to the axis of each eye singly is lost. Each instrument has its special uses, but the eye requires training for both, and in all microscope practice *fatigue of the eye* physiologically affects the distinctness of vision. We know that too much light involves fatigue of the retinal perceptive faculty from over intensity of impression. "*In a single minute the impression produced by a bright surface has lost from a quarter to half of its intensity, and yet the observer does not notice this fact until contrast brings it before him.*" (See Helmholtz's Popular Lectures, page 225.) Too little light, again, involves fatigue from strain of attention, and consequent tremor of the muscles of the eye. For the definition of delicate outline depends upon trustworthy recognition of subtle gradations of light and shade, and suffers in proportion as the brightest parts of a picture fade. If the absence of light produce a *lower* tone than is requisite for definition, the mental direction of the movements of the eye for observation of contrasted light and shade is not called into action, or if forced it fatigues still more. If, again, an object presents surfaces of relatively large area which are much brighter than the other parts, corresponding portions of the retinal percipient surface become fatigued, and vision is disturbed by *after images*, whilst those parts which have relatively too low a tone fade from sight. The act of seeing thus exercised upon images of very minute objects in the midst of large bright fields is greatly burdened in the attempt to discern fine structure. On the other hand the more an object is needlessly magnified the less clearly will its outlines be defined because the delineating pencils of light are scattered and the intermediate details lose needful light and shade. Whether therefore the brightness of image be too much with low amplification, or too little with high amplification, the eye will not perceive what the microscope with proper management can nevertheless perfectly delineate.

Although we have barely glanced at a few of the principal defects inherent in the anatomical constitution of the eye, the limits of this paper have been so far exceeded that it is impossible to enter upon any discussion of the imperfections of the dioptric media of the eye considered as an optical apparatus. It has long been known that spherical and chromatic aberrations do exist in the most healthy organ; and it has been the province of the physiologist to account for the general perfection of vision, in spite of the very numerous structural and functional defects of the eye. It has, for instance, been shown how accommodation for focal distance is provided for by muscular movement operating upon the position of the lens, and how imperfect form and colour are counteracted, and contrast of light and darkness, appreciated by the simple act of changing the axial direction of the eye. But it is necessary to go much further than this in any attempt to set up a theory of vision. In the first place, the sensation of sight has to be explained, or at least the furthest boundary of physical impression has to be traced, and the means discovered by which the excitation of the separate nerve-fibrils is produced. And there seems little reason to doubt that anatomical investigation and physical science will eventually accomplish these ends. A theory of vision, so far as it relates to the complete and accurate apprehension of the form and colour of external objects, may then be possible. Meanwhile the facts which have been ascertained from the study of the dioptrics of the eye, cannot be disregarded in our estimate of microscope vision. For the capacity of the eye as an optical instrument has a direct relation to the performance of the microscope ; whilst as a percipient or sensory organ it dominates over the whole subject of light and its properties. The limit of vision, whether by the unassisted eye or when assisted by optical apparatus, remains fixed by the distinguishing power of the retina. And under ordinary conditions of illumination, the images formed by the eye in its normally healthy state are equal in delicacy and accuracy to the limits which the dimensions of the retinal cones and rods set to the delicacy and accuracy of sensation. To these limits the microscope sets, properly speaking, no opposition. The function of this instrument is to bring minute objects within the powers of recognition which the eye possesses. And as a magnifying instrument it can do more than this; but the failure lies in the conditions of illumination on the one hand, and in the limits of visual perception on the other.

Notes on Carboniferous Encrinites from Clifton and Lancashire.

BY J. G. GRENFELL, B.A., F.G.S.

Read before the Geological Section of the British Association, Bristol, 1875.

I HAVE been fortunate in obtaining some fine specimens of Encrinites from the base of the Carboniferous Limestone in the gorge of the Avon. They occur in the two lowest beds of the Black Rock Quarry, just above the Lower Limestone Shales. Four genera are found in the two beds—*Poteriocrinus, Cyathocrinus, Actinocrinus, Rhodocrinus*—which latter genus does not include Phillips' *Gilbertsocrinus.* By far the commonest species is *Poteriocrinus plicatus* (Austin), of which I have obtained a fine series. Hitherto only the body had been found—the arms, proboscis, and stem being unknown. I will now describe this species, and in so doing, and throughout the paper, I have adopted De Koninck's nomenclature for the plates which form the body and arms. (*See plate VI. figs* 1 *to* 4, *and plate VII., figs.* 1 *and* 2.)

I can find no traces of the three concealed plates above the column mentioned by Phillips and Major Austin, and whose existence was doubted by De Koninck.

The *basals* are five, as described by De Koninck and Major Austin. They articulate to the column by radiating ridges and furrows. Sometimes at the points they are lowered, so as partially or entirely to overlap the top point of the column.

The five *subradials* are well described by De Koninck and Major Austin. All their edges articulate by ridges and furrows at right angles to the surface of the plate.

The *radials* are seven in number; of these the first only was known to the above-mentioned authors. These first radials articulate to the subradials by ridges and furrows, but this is not the case with their lateral articulations to one another. They are followed by six radial plates, and a cuneiform one, where the first bifurcation takes place. Then follow twelve *brachial* plates and a cuneiform one to the second bifurcation; then an uncertain number, not less than twelve, to the third bifurcation; and then eighteen and a cuneiform to the fourth bifurcation. The number of rays is thus eighty.

All the plates of the arms are more or less laterally wedge-shaped, with the thick end of one fitting the thin end of the next. Up to the second bifurcation they all articulate by radiating ridges and furrows, and the rest probably do the same. This articulation of the arm-joints has not commonly been observed.

The *anal* plates are five in number, while De Koninck gives for the genus 4 or 6, and they do not agree with his generic figure. They are arranged in two vertical rows; the two lowest are pentagonal, the two next are hexagonal; the last is probably hexagonal. (*See plate VI., fig.* 2.)

The proboscis is by far the most interesting part of this species, being composed certainly of upwards of 1000, and probably of upwards of 1300 separate plates, and exhibiting a structure hitherto undescribed amongst the Crinoids. Professor De Koninck, speaking of the probosces of the Crinoids, says that some are formed of many hexagonal plates, as *Poteriocrinus gracilis*, (M'Coy), others are membranous and formed of a single piece. As he does not describe any membranous ones in his work. I fancy he may have got this notion from Austin's figure of *P. crassus*, or perhaps from a Clevedon specimen in the British Museum in bad preservation, which looks very much like a wrinkled membranous tube.

These specimens exhibit the following structure. One of them is 4¼ inches long by ¾ inch wide. Above the anal plates are two plates side by side, about twice as wide as long, which have two prominent lateral ridges on each side; these are followed by two shorter plates which have two lateral ridges. These four plates give strength to the base of the proboscis, and are followed by the ordinary plates. The proboscis is formed of long narrow plates, arranged in five horizontal rows, and set at right angles to the axis of the proboscis. The most prominent of these are pairs of plates bearing high ridges, which are pressed against each other so as to form a single strong ridge across the proboscis. Of these there are in one case 43. Each of these pairs is separated by three, and in one case by five plates, of which the central one is the largest, and all of which are rather higher in the centre, so as to form five longitudinal ridges (*Plate VI., figs.* 1 *and* 3.) These smaller plates articulate by crenulated edges.

The interior of the proboscis shows the underside of the three intermediate plates, but instead of the two ridged plates shows only one broader one of which the ends are bifurcated. They thus appear to underlie and hold together the ends of the ridged plates.

I have found some broad plates free, which appear to have a deep socket at each end, and which seem to be different from the plates visible on the exterior. It is possible that the bifurcation mentioned may be only a section of these sockets, but further investigation will be required to settle this point. (*See plate VII., fig.* 2.) Among the detached plates I have found some short ones which are bent at a high angle, and which do not seem to have been subjected to compression. (*See plate VII., fig.* 2.) It is difficult to assign to these their proper place, unless the proboscis was not circular but oval in section, on one side at least. The position of the proboscis was not central but on the side of the anal plates; this is evident in nearly all the specimens exhibited. In the interior of the head of one specimen are a number of very small plates, which, perhaps, were situated on the base of the proboscis on the opposite side to where it joins the anal plates.

The stem is smooth; the joints shorter near the summit, and articulating by radiating ridges and furrows. In one specimen the first side arm appears at a distance of eight inches from the head, is very small and nearly an inch from the next. At eleven inches they become very numerous and larger. Another specimen showing only the base of the stem has fifteen to twenty side arms in the space of two inches, and it shows that the stem diminishes in diameter towards the base. The plates from which the side arms spring are rather thicker than the rest. One of these side arms, detached, is four inches long. The plates composing the side arms do not exactly fit one another as pointed out by De Koninck. The average length of the stems seems to be about thirteen or fourteen inches. Length from top of column to top of proboscis 4·8 inch. The rays were probably about the same length as the proboscis.

Poteriocrinus rugosus (Grenfell). (*See plate VII., figs.* 3, 4, 5.)

I propose the above name for a new species of Poteriocrinus in the Museum at Clifton College. It was found in the Lower Limestone Shales in the Avon gorge, and formed part of the Bernard collection.

The body is conical, the base slightly concave, pentapetalous, the edges crenulated. The lower edge of the basals partially overlaps the base as shewn in Pl. vii. fig. 5. An obscurely pentagonal, nearly circular line marks the margin of the part of the column in which, as in the recent Pentacrinus, the calcareous matter was more loosely arranged, and which contained the longitudinal fibres. This portion might conveniently be called the fibriferous area: it is well-marked in Rhodocrinus.

The *basals* are five, wider than long, and shaped somewhat like *P. plicatus*. The alimentary canal is small and pentapetalous.

The *sub-radials* are five—three pentagonal, the other two hexagonal. All have their lateral articulations depressed, so as to give a characteristic rounded shape to the plates.

The *radials* are three, wider than long; they are rounded in the same way as the sub-radials. The first articulates to the second by its whole breadth; from the third or axillary radial spring two rays which, in one case, are both simple up to the seventh plate where they are broken off; in two other cases, one ray remains simple up to the twelfth plate where it is broken off, while the other bifurcates a second time after the third plate, and the two simple rays are side by side with the divided rays outside. It is noticeable that these extra rays do not occur on opposite sides of the anal plates as if to protect that portion, as suggested by Major Austin in the case of *P. pentagonus.*

The first radial articulates to the second by two ridges. The other two arms are wanting. The channel along the arms is very wide and deep.

The *anal* plates are five, arranged in two vertical rows as in *P. plicatus;* the lowest is pentagonal, the rest hexagonal; all their angles are depressed. (*See plate VII., fig.* 4.) The articulations of the arm joints have an irregularly waved edge.

The surface of the body plates is rough; that of all the plates of the arms is strongly wrinkled, especially at the sides.

The third radial is remarkably wide in proportion to the calyx.

This species resembles *P. pentagonus* and *longidactylus* (Austin) in shape and general arrangement of parts; it is well distinguished from them by the depression of the angles and lateral articulations, and by the roughness of the surface. The height of the calyx is ·3 inch; diameter, ·4 inch; total length of the specimen as figured, 1.3 inch; width of third radial nearly ·3 inch.

Rhodocrinus verus (Miller). (*See plate VII., figs.* 6, 7.)

I exhibit a fine specimen of this species from the lowest beds of the mountain limestone already mentioned. The arrangement and ornaments of the plates leave no doubt that this is the species on which Miller founded the genus. The arms, however, were unknown to him, and the column had not been found attached to the head.

The arms are ten in number. They bifurcate only once, so that the number of rays is twenty.

The *brachials* are six in number and adhere to the calyx; above the sixth axillary one are two plates adhering laterally to each other; above this the arms are free and composed of a double series of joints which are closely tentaculated.

The *stem* is cylindrical, and composed of alternately thicker and thinner joints, but the difference is not great.

It appears to have been of great length in proportion to its thickness, as a detached stem, apparently of this species, is over a foot long and shows no signs of head or side arms.

The alimentary canal is small and apparently circular, the fibriferous area is pentapetalous. Height of calyx ·7 inch; from base to top of arms two inches; width of calyx ·9 inch.

This species is evidently very local, as the British Museum has only one very bad specimen; Jermyn Street Museum none; and Major Austin two from this neighbourhood, also in poor condition.

Miller's specimens have unfortunately disappeared from the Bristol Museum.

It is a question whether this species should be called *verus*. Miller's figure (Crinoidea, *plate I.*, *fig.* 1) is from a drawing sent him by Mr. Stokes, of Dudley, and is a Silurian fossil, quite distinct from the Carboniferous one, and probably belongs to another genus. If they belong to the same genus, one of the two must evidently be re-named. Professor Phillips applied the name *verus* to the Silurian species, and did not believe that this species was found in the Carboniferous Limestone at all.

Professor De Koninck also writes to me that the name *verus* must be retained for the Silurian species, as it appears in all lists of Silurian fossils.

On the other hand it is quite certain that Miller founded his genus on the Carboniferous species, as his detailed drawing of the plates agrees exactly with the one exhibited. In Morris' catalogue it is quoted as Carboniferous, but with a note on Phillips' view.

If the Silurian species really belongs to another genus they may both retain the name. Major Austin believes that none of the Silurian genera of Encrinites survived in Carboniferous times. I have not seen the Silurian specimen, and, therefore, cannot speak positively, but in any case it seems to me that the name *Rhodocrinus verus* should be retained for the Carboniferous species, as that is clearly what Miller intended. If, however, geologists generally adopt De Koninck's view, I should propose that this be called R. radiatus.

Rhodocrinus verisimilis (Grenfell). (*See plate VII., figs.* 8, 9, 10.)

I have given the above name to a new species of Rhodocrinus found with the last, which in many ways it closely resembles. The general arrangement and shape of the plates of the body agree with Miller's detailed figure of the genus. The *sub-radials* are hexagonal and wider than long.

The *radials* are three, the first heptagonal; second, hexagonal; third, normally heptagonal. They bear prominent longtitudinal ridges like *R. verus* and *stellaris*, but in the present species these are wider and flatter; that on the second is wider in the middle, and the prominences are continuous, not interrupted as in *R. stellaris.*

The arms are ten. The *brachial* plates five to the first bifurcation; the two lowest are hexagonal, and adhere to the calyx; they are short, wide, and flat; are followed by three plates to the second bifurcation, which are also short, wide, and flat; after this the rays, as in *R. verus*, are composed of two series of joints, and are tentaculated, still remaining comparatively broad for their length. Total number of rays, forty.

The shape and arrangement of the brachials closely resemble those of *R. verus* (*see plate VII., fig.* 10), and are important, as I hope to show that they serve to separate these species generically from Phillips' genus Gilbertsocrinus. The *inter-radials* have triangular depressions at their angles, so as to form star-shaped ornaments as in *R. verus*, but the centre of the star is here much wider. The *stem* is cylindrical; the joints alternately thicker and thinner; the alimentary canal small and circular; the surrounding fibriferous area is pentapetalous. Height of calyx, ·38 inch; diameter, nearly ·6 inch; length from the base to top of arms, 1·1 nch. One of the specimens in my collection, which is in bad condition, seems to be this species; it has the dome considerably elevated.

Verisimilis is distinguished from *verus* by its smaller size, by the rays being wider, shorter, flatter, and double the number, by the shape of the second brachial, and to a lesser extent by the ornaments of the radials and inter-radials; from *stellaris* (De Koninck), and *granulatus* (Austin), by the star-shaped ornaments on the inter-radials which are absent in those species. The four specimens in my collection are the only ones I have seen, unless a very bad specimen from Clevedon in the British Museum belongs to this species.

I now pass on to the Lancashire species, on which Phillips founded his genus *Gilbertsocrinus*, and I hope to show that, although his generic description is inaccurate, yet the genus is a good one and must be retained. His description is as follows:—"Base hollow; basals five, forming a pentagon; suprabasals (the subradials of De Koninck) five, hexagonal, forming a decagon with five re-entering angles, from which spring five heptagonal first costals, five hexagonal second costals bearing a pentagonal scapula, supporting joints which combine into round arms perforated in the centre. (These costals and scapulæ are the radials of De Koninck). The first intercostal is pentagonal.

De Koninck and Le Hon have shewn that the whole of this description, as far as regards the number and arrangement of plates, applies equally well to Rhodocrinus, and, therefore, they do away with the genus Gilbertsocrinus, but they take no account of the very peculiar structure of the brachials above the scapulæ, which Phillips does not describe in words, but of which he gives a detailed drawing in the case of *G. bursa.* Rofe, and I believe Billings also, have given up Gilbertsocrinus.

The inaccuracies in Phillips' description are his making the scapula or third radial, and the first intercostal or inter-radial pentagonal. I have examined the specimens of *G. bursa* in the British Museum, and find that in every case the third radial is normally heptagonal, though a plate is often wanting on one side or the other, and I have a specimen in which this plate is in one case pentagonal. *G. calcaratus*, also in the British Museum, has the third radial normally heptagonal.

The British Museum specimens of *bursa* have the first interradial generally pentagonal, but I have three specimens, which I believe to be this species, in which this plate is generally hexagonal. There are a considerable number of specimens labelled *G. mammillaris* in the British Museum, and in all of them this plate is hexagonal. It is quite clear then that these two points must be removed from the generic description.

Professor McCoy unfortunately gave the name *abnormis* to an Irish specimen, which has the third radial heptagonal and first intercostal hexagonal, on the ground that in all others of the genus these plates were pentagonal. His specific characters thus fall to the ground, and the only points in which his description and figure differ from *bursa* are, the larger size, the absence of marked depressions at the angles of the plates, and the statement that the proboscis is central.

The depressions at the angles are not well marked in all specimens of *bursa*, and therefore I do not attach much importance to this. With regard to the proboscis, I would remark that no other species of *Gilbertsocrinus* has a proboscis at all, and that the figure does not prove the existence of one in this case. What McCoy calls the proboscis looks just like a raised mouth at the top of a rather conical dome. In this it much resembles a specimen of Mr. Rofe's in the British Museum, which has a row of nearly vertical plates round the mouth, but which cannot fairly be said to have a proboscis. It is true that *bursa* has the mouth eccentric, but I cannot help thinking that some further proofs are necessary to shew that this is not merely a large specimen of *bursa*.

Mr. Rofe writes to me that no reliance can be placed on the number of sides of the plates, especially in the genus Rhodocrinus or Gilbertsocrinus, as they frequently vary on the same specimen. I cannot quite agree with this, as regards the radials, because the specimens shew that *bursa* has the third normally heptagonal, and *mammillaris* normally pentagonal. Careful observation will always show which is the rule.

The grounds on which I believe that Phillips' genus Gilbertsocrinus must be retained are, that all the specimens of *bursa*, *mammillaris*, *calcaratus* and two or three new species which I have examined, agree in the very peculiar structure of the brachials and the arm-bases The first brachial is hexagonal; the second also hexagonal, but channelled at top and leading into an orifice which opens into the perforation through the arms: the arm-bases are set on at right angles to the surface of the body, and form a kind of roof over the above mentioned orifices, *(Plate VII., figs.* 11, 12.*)* The orifices are well seen in Phillips' detailed drawing of *bursa.* The axillary plates also between the brachials are developed to a much greater extent than in any other genus, and the irregularity of the plates above the second brachial, surrounding the orifices and the arm bases, is also characteristic. *(Plate VII., fig.* 12.*)*

The difference between this complicated arrangement and the straight-forward arrangement of the brachials in the true Rhodocrini, *e.g.*, *verus*, *verisimilis*, and *granulatus*, is quite sufficient to establish a generic difference between these forms, especially as these orifices are not found, so far as I am aware, in any other genus. The channel at top of the second brachial is fitted in one of Mr. Rofe's specimens with a small semicircular plate which he calls a fillet—it is figured in the Geol. Mag. vol. 2. Mr. Rofe there suggests that these orifices are ovarian, but it seems to me more probable that they are for the purpose of admitting water into the interior. Recent researches on the living crinoids have established the fact, that the ciliæ of the arms set up a current of water which travels down the groove in the arms, passes also in grooves over the surface of the dome, then enters the cavity of the body, and passes through a membrane which filters off the minute organisms which constitute the food of the crinoid, and, finally, passes out through the proboscis. This latter is, thus, simply an efferent tube which serves to carry to a distance from the arms, the water which has already passed through the body.

In the fossil crinoids Mr. Rofe has shown that the only difference is, that the current enters the body at the base of the arms and passes to the central cavity through covered channels under the dome, instead of in open grooves on the top of it.

As the genus Gilbertsocrinus has no proboscis, there is a danger of the water which has passed through the body being immediately returned to it by the arms. This difficulty is met by the peculiar structure I have described. In the first place, the groove in the arms is not continued to the base, but becomes a central passage. This passage is, further, very small, so that only a limited quantity of water passes in that way. The arms, again, are set on at right angles to the body so as to be as far as possible out of the way of the issuing water. In some cases the arms contract in size very remarkably immediately above the base. To meet the deficiency in the supply of water through the arms these openings are made below, and the current from the arms passing over the top of these openings, draws in, mechanically, a supply of fresh water from below, which is further protected from mixing with the issuing water by the over-hanging roof of the arm-bases. This explanation seems preferable to the other because it is unlikely that this genus only should be provided with ovarian apertures, while the absence of a proboscis gives a definite reason why this genus should find it advantageous to have these subsidiary openings. That the perforations in the arms are really ambulacral, and are not for the passage of muscles as has been suggested, seems to me clear from the fact that if they were filled with muscle there would be no means by which the current set up by the tentacles could reach the interior, as there is no external groove.

The genus Gilbertsocrinus may now be thus defined—basals 5; sub-radials 5; radials 3; brachials several, generally irregular; the second brachial channelled at top, and leading into an orifice which communicates with the perforation in the arms; axillary plates well developed; arms round, and generally set at right angles to the body; plates of body generally tuberculate. It will include the following species—*bursa* (Phillips), *abnormis* (McCoy), *calcaratus*

(Phillips), *mammillaris* (Phillips), *Koninckii* (Grenfell), two or three new species which I hope soon to work out, and probably *simplex* (Portlock) which I have not yet seen.

Rhodocrinus on the other hand will contain *verus* (Miller); *verisimilis* (Grenfell); *stellaris* (De Koninck and Le Hon) *uniarticulatus* (De Koninck and Le Hon) *granulatus* (Austin), and probably *globosus* (Phillips) and *costatus* (Austin).

I will conclude by describing a new species of Gilbertsocrinus which I have named *Koninckii* after the distinguished Professor, to whom all students of the Carboniferous Crinoids are so much indebted,

G. Koninckii. (*See Plate VII, figs.* 11, 12, 13.) Shape somewhat conical, with prominent arm-bases, base deeply concave, basals not seen, sub-radials considerably longer than wide.

Radials—first heptagonal, large, and bearing a large pointed tubercle; second hexagonal, the two upper side faces small, so as to make the plate nearly square; third, pentagonal; one of the rows of radials presents the very unusual irregularity of having four radials instead of three—of these the first is heptagonal, the second and third pentagonal, each having lost one of the side faces, though on opposite sides; fourth, pentagonal. I presume this is an accidental irregularity in this specimen.

Brachials—first, pentagonal; second, hexagonal, chanelled and with the usual orifice; above are three or four elongated plates surrounding the circular base of the arms—these latter are set at right-angles to the body, project considerably, and have a central perforation which is larger than in most of the genus. Axillary plates, three; the lowest hexagonal; of the others, one is hexagonal and one pentagonal. Inter-radials twelve. The dome is considerably wider than the calyx, slightly elevated; the plates are as large as those of the body. The mouth, eccentric.

All the plates of the body and dome, with the exception of those round the base of the arms, the second brachials and the sub-radials have pointed tubercles. The five prominent tubercles round the base distinguish this species from all but *G. simplex* (Portlock).

From that species it differs entirely in shape, in its smaller size, in the narrowness of the sub-radials, and in the presence of the tubercles on the body plates.

Height, nearly ·7 inch.
Diameter across arms 1 inch.
Diameter across base ·5 inch.

This specimen comes from Clitheroe.

EXPLANATION OF PLATES.

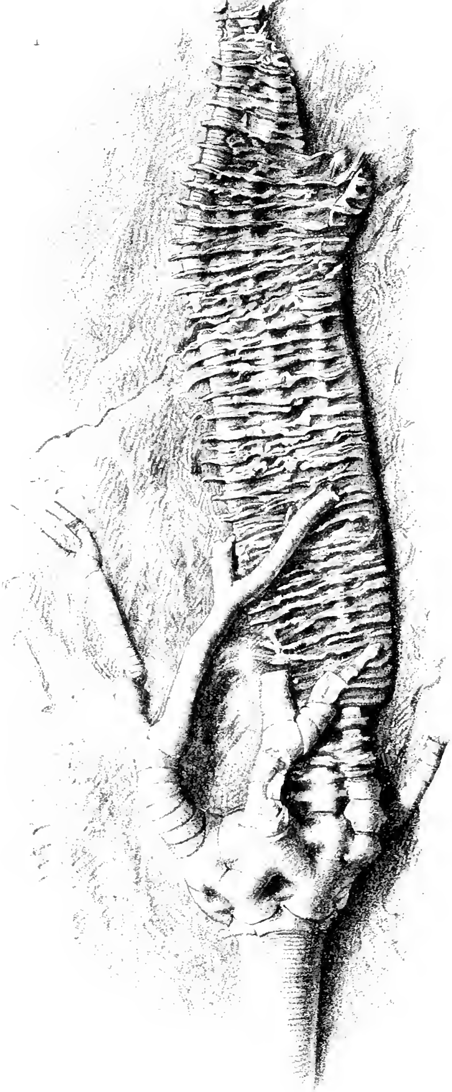
PLATE VI.

1. Poteriocrinus plicatus, (Austin), natural size.
2. Anal plates of ditto.
3. Portion of proboscis of ditto, enlarged.
4. Another specimen, shewing stem and side arms. Reduced in size.

PLATE VII.

1. Poteriocrinus plicatus. Proboscis from a slab, with three heads and seven stems.
2. Detached plates of proboscis of ditto, on the same slab as Plate VI., fig. 1.
3. Poteriocrinus rugosus. n. sp.
4. Side view of the same, shewing anal plates.
5. Base of ditto.
6. Rhodocrinus verus. (Miller.)
7. Plates of ditto, enlarged.
8. Rhodocrinus verisimilis. n. sp.
9. Ditto.
10. Arrangement of plates of ditto.
11. Gilbertsocrinus Koninckii. n. sp.
12. Arrangement of plates of ditto.
13. Plates round the arm-bases of ditto.

1



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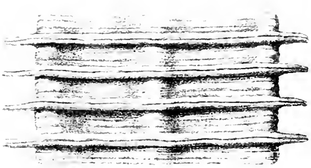

E.C. Lavars del.
J. Lavars, lith. Bristol.

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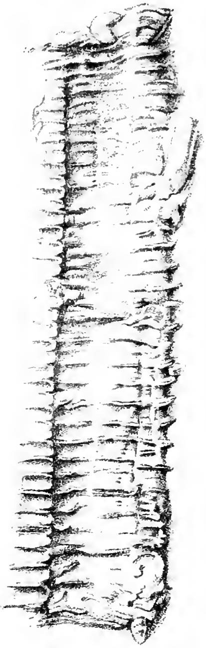

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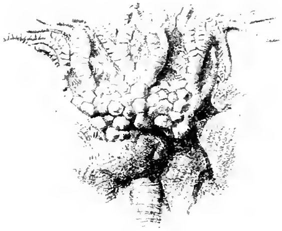

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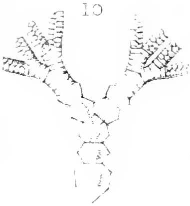

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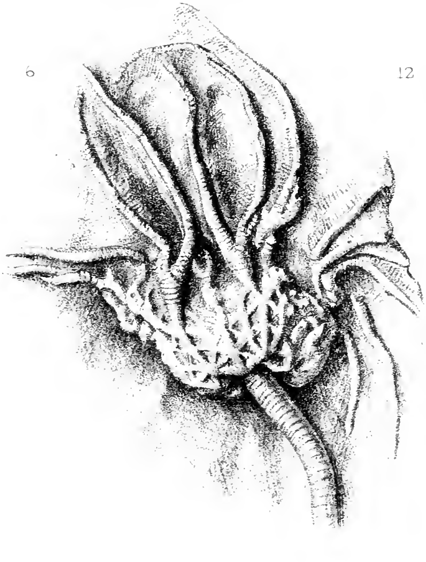

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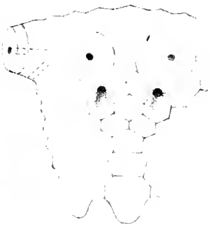

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E. C. Lavars del.

J. Lavars lith. Bristol

Rain-fall at Clifton in 1875.

BY GEORGE F. BURDER, M.D., F.M.S.

TABLE OF RAIN-FALL.

—	1875.	Average of 23 Years.	Departure from Average.	Greatest fall in 24 hrs.		Number of days in which 0·1 in. or more fell.
				Depth.	Date.	
	Inches.	Inches.	Inches.	Inches.		
January	5·144	3·449	+ 1·695	0·720	1st.	25
February ...	2·248	1·989	+ 0·259	0·789	6th.	11
March.........	1·455	2·160	— 0·705	0·651	7th.	7
April	2·091	1·973	+ 0·118	0·728	7th.	9
May............	2·867	2·376	+ 0·491	0·757	6th.	15
June	3·525	2·561	+ 0·964	0·687	13th.	16
July............	5·991	2·818	+ 3·173	2.900	14th.	15
August	1·785	3·270	— 1·485	0·541	8th.	12
September ...	4·599	3·354	+ 1·245	0·937	21st.	16
October	6·977	3·681	+ 3·296	0·877	9th.	20
November ...	6·085	2·531	+ 3·554	1.295	13th.	17
December ...	1·280	2·548	— 1·268	0.278	31st.	12
Year.	44·047	32·710	+ 11·337	2·900	Jly.14th.	175

Remarks.—In the foregoing table are shown the quantities of rain measured in each month of 1875, and in the whole year, the averages derived from 23 years' observations, and the departure in each case from the average. To these particulars are added the heaviest falls for the several months, and the number days in each month on which rain fell to the amount of a hundredth of an inch or upwards.

It will be observed that the total rain-fall of the year exceeded 44 inches. So wet a year has not occurred before within the period of observation, the nearest approach to it having been in 1872, when the quantity was 42·366 inches. The excess in 1875 appears still more remarkable when we take into account the latter part of the preceding year. Strictly the rainy period extended from August 1874, to November 1875. Out of these sixteen months there were but three in which the fall was not above the average, and the total excess in the sixteen months was nearly 18¾ inches.

The heaviest monthly fall in 1875 was in October, which is the most rainy month on a long average. The amount collected in that month was close upon seven inches. January, July and November were also exceedingly wet, the departure from the average being greater in the last named month than in any other.

The two heaviest diurnal falls occurred on the 14th of July and on the 13th of November. On the former occasion no less than 2·9 inches fell within 24 hours, a quantity exceeding any previously recorded here as having fallen in the same interval of time.

The year was not remarkable for snow. At its opening three inches lay upon the ground, and at no subsequent period was the depth so great as this.

Reports of Meetings.

GENERAL.

JANUARY 7th, 1875.—At the first evening Meeting of year, Dr. Burder read "An Account of the Rainfall in Bristol during 1874;" this was printed by order of the Council in last part (Vol. I, Part 2.) Mr. Leipner then made a communication on the "Land and Freshwater Mollusca of the Bristol District," exhibiting a collection of all the species; the list was printed in Vol. I., part 2.

February 4th, 1875.—Dr. H. Fripp, Vice-President, gave a lecture, entitled "A chapter on the choice of a Microscope," illustrated with a large collection of instruments, both English and foreign,—the advantages of each being gone into in some detail. Reference was made to Dr Abbe's writings, a translation of part of which was printed in Vol. I., Part 2, and a second instalment in the present Part.

March 4th, 1875.—Mr. W, W. Stoddart, F.G.S., F.C.S., gave a verbal exposition of the continuation of his paper on the Geology of the District, viz., Part III., Carboniferous. The text appears above. In the discussion which ensued, Mr. Grenfell doubted whether *Terebratula hastata* was found so low down as the author had put it. From the Gully quarry he had obtained a fine example of corals *Michelinea* and *Syringopora,* and a unique *Aviculo-pecten.* The iron-ore deposits he considered were of Triassic age; and as a source of the iron, suggested that it may have been derived from the Coal Measures by solution. Mr. Wollaston remarked that in the Millstone Grit series he had found laminæ of $\frac{1}{8}$-inch thickness showing Oolitic structure; and he doubted whether in such cases it would be formed by strong currents: he considered such laminæ must have been deposited in still waters. Mr. E. Tawney said he followed the author in holding that the lowest shales belonged truly to the Carboniferous and not to the U. Devonian, as Mr. Etheridge has suggested (*Q. J. G. S.*, XXIII., p. 692), for he has never been able to find any fossil identical with those of N. Devon.

April 1st, 1875.—Mr. E. Tawney read a paper on "Professor Renevier's Geological Nomenclature," exhibiting that writer's large stratigraphical diagram of formations.

May 6th, 1875.—Annual Meeting. The President and other Officers were re-elected, except the Treasurer, who resigned from pressure of affairs. Mr. W. Derham, of Henleaze Park, was elected Treasurer. Three new Members of Council were elected, viz., Messrs. W. W. Stoddart, S. Derham, and A. E. Hudd, in lieu of those retiring by rotation. The Report of the Council was read and adopted. The meeting then passed to the consideration of a new code of Rules; the meeting was adjourned, and at this their adoption was completed.

General Excursion, July 7th, 1875, to Wells and Glastonbury.—A party of seventeen left Bristol by the 8.0 train for Wells. They visited the Cathedral and Palace grounds. Some of the party went to call on the Mayor with regard to the forthcoming excursion of Members of the British Association to Wells during the Bristol Meeting. The party then left for Glastonbury, ascending the Tor. The geologists were not very successful in finding good exposures of the U. Lias beds.

October 7th, 1875.—Mr. E. Wheeler made an interesting communication "On the Birds of the Bristol District," exhibiting part of his private collection, containing the more interesting species and a good series of nests. The text of the paper appears above. Mr. Charbonnier then exhibited a series of silk-producing Moths, including the following species: *Bombyx Yama-mai*, *Pernii*, *Cynthia*, (Ailanthus-worm), *Cecropia, Polyphemus, Promethia, Luna.* The Tusseh-worm was not in the collection.

November 4th, 1875.—The Rev. W. Hargrave made a communication "On Local edible Fungi," exhibiting many specimens, and explaining whereabouts and when they were to be found, and how they should be cooked. During the discussion, Mr. Leipner said that on the continent there was a notion that to tell whether a fungus was poisonous an onion should be cooked with it, and if the onion did not turn black then the fungus was wholesome; he did not believe, however, in any general rule of this sort,—the only safe way was to identify the species. Mr. Stoddart mentioned cases of illness from eating the stalks of the common Mushroom. Mr. E. Tawney read a paper "On the Limestone of Cannington Park." Mr. Stoddart then exhibited two cases of a double orange, one within the other: the outer one, which seemed of the ordinary shape, when cut open exhibited a smaller one within, perfectly complete, placed excentrically.

December 2nd, 1875.—Before the commencement of the business of the evening, the chairman, Dr. Fripp, Vice-President, proposed the following Resolution, which was carried unanimously: "Resolved, that the sincere sympathy of the Members of the Bristol Naturalists' Society be offered to the relations of the late Mr. William Sanders, F.R.S., F.G.S., whose character and scientific attainments, and whose important services as President of this Society, the Members desire to acknowledge and record with marks of their highest admiration. Entertaining the fullest sense of the loss which the Society has sustained through the decease of its lamented President, this expression of sympathy and cordial tribute of respect and esteem for the public and private worth of their late Associate is directed to be communicated to the family of the deceased."

Mr. W. W. Stoddart, F.G.S,, then continued his account of the local Geology, lecturing on the Coal Measures, being Part IV. of the series. This appears above.

BOTANICAL SECTION.

FEBRUARY 18th.—The Annual Meeting of this Section. The Treasurer's Account was audited and passed. Mr. Charbonnier moved, "That the President and Secretary be re-elected, with a vote of thanks for their past year's services;" which resolution was carried unanimously. A Sub-Committee of six Members was then chosen for preparing a collection of plants for the Local Museum in connection with the visit of the British Association to this city.

March 27th.—The first botanical walk this season was taken to Combe Dingle, the members meeting on Durdham Down. *Narcissus Pseudo-narcissus* was gathered below Adams' farm; *Lemna trisulca* in the rivulet; *Viola hirta* on Combe Down; and *Myosotis collina* by the old quarry. In the evening the Local Museum Committee, at the invitation of the President, met at his residence, 47, Hampton Park, and examined the plants collected during the day; and after having refreshed themselves with a most liberal supper, Mr. Leipner took the chair, and the marking off the local plants, as per London catalogue, was completed at 11 p.m.

May 1st.—Taking the train at Clifton Bridge for Portbury, we walked from thence to Portishead by way of the Marsh. At Portbury Station the bank was covered with *Petasites vulgaris;* while the *Chrysosplenium oppositifolium* grew in clusters on the margin of the rivulet. The Water Ranunculus covered the rhines with a white sheet of flower; and *Armeria maritima* was bursting its sheath on the sea shore. Arriving at Portishead we accepted an invitation to spend the evening at Avon Villa, the residence of Captain Dayas.

May 29th.—Meeting at Clifton Down Station, we took an early train to Stapleton Road; here we alighted, and taking the road we came to Stapleton Bridge, and turning to the right, we struck into the fields, and entering Frome Glen, we found excellent ground for botanizing, with its river, woods, quarries, marsh, and meadows. *Vicia* and *Geranium* of many species were gathered; also *Caltha palustris* in seed, *Cardamine impatiens*, *Sarothamnus impatiens*, &c. At 5,30 we heard voices using botanical names, and hailed with much pleasure Mr. Leipner and the medical students who had come by a later train. After a further search we filled our vasculums, and staying a short time in Stapleton for refreshments, we returned home a more numerous party than at starting.

September 4th.—Proceeding by train to Portishead, we passed through the village, ascending the hill by Simmery Lane, we gained the top road, and having permission to ascend the tower at the farm, we much enjoyed the magnificent view. Continuing our walk, we descended the hill at the Nore, and skirting the shore we finished a very pleasant ramble by partaking of tea at the Hotel. Amongst other plants collected were *Tanacetum vulgare*, *Leptospermum officinale*, *Orobanche minor*, *Chichorium Intybus*, and *Crithmum maritimum*.

October 21st.—The first autumn Meeting was held at the Museum and Library, the President being Chairman. The minutes of the Local Museum Committee and of the Summer Excursions were read and signed. Mr. G. N. Harris was enrolled a Member. The President described certain edible Fungi that were very plentiful in the neighbourhood at this time of the year.

November 18th.—The President after signing the minutes of the last Meeting, drew our attention to the serious loss we had sustained since we last met, in the death of one of our original members, William Sanders, Esq., Fellow of the Royal Society of London, and President of the Bristol Naturalists' Society, who had that morning been committed to his last resting place,—several of the Members present having, as a last token of respect, followed his remains to the tomb.

Dr. Burder was enrolled a Member.

Mr. Leipner gave the subject for the evening, "Microscopic Fungi," confining his remarks to Epiphytic Fungi, and referring not only to the "alternation of generation" of some of these plants —as, for instance, Uredo and Puccinia—being various forms of the plant at different times of the year, but also to certain phenomena in the animal world to which the same name, "alternation of generation," had formerly been applied. Explaining the true nature of the latter in the case of the Aphis and Polyps, he showed the essential difference between them, and the changes observed in some Epiphytical Fungi. Mr. Leipner presented several specimens to the Herbarium.

December 16.—The subject for the evening was, "New Zealand Flax and Kauri Gum." The Honorary Secretary, Mr. C. B. Dunn, gave a succinct account of the so-called New Zealand Flax, showing by specimens received from the Orewa Flax Mills, Auckland, and by native prepared Flax, that *Phormium tenax*, (var. Tihore) produces a fibre of great strength, and when well prepared, is of a beautiful glistening appearance, and very soft to the touch. Phormium belongs to the natural order Liliaceœ. Dr. Hooker says, "There are two species, viz., *P. tenax*, seed-pod erect, 1½ to 3 inches long, straight, leaves very strong; *P. Colensoi*, seed-pod pendulous, 3 to 7 inches long, twisted, leaves weak. The former grows to 15 feet, the latter to 7 feet high. In the Province of Auckland the former abounds, and there the manufacture is a success; but in the South Island the latter abounds, and there the manufacture is a failure. The fibre is obtained from the leaf, the vascular tissue running continuously the whole length. The leaves average 5 feet, and in appearance are not unlike the common flag, *Iris Pseudacorus*, of our marshes." The various modes of manufacture were then described, from the scratching with the nails by the Maori to the most approved machinery. The principal use the fibre is adapted for is that of the manufacture of rope, it being equal to Manilla, and considered by some to be stronger.

Mr. Dunn then took up the second subject on the notice paper, "Kauri Gum." This Gum is largely imported from Auckland, New Zealand, and is dug up out of the ground, found on an average of 9 inches below the surface, and met with in untimbered fern ranges or swamps. The explanation of its being there found is thus given by the inhabitants: "Very large tracts of country in this Province were once covered with magnificent forests of Kauri Pine, *Dammara Australis*, attaining the height of 200 feet. When these forests were burnt the Gum (which issues from wounds in the tree, and is occasionally seen hanging like icicles from the branches) was by the action of the fire driven down, and forced its way through the roots into the earth." This is the Gum that is exported principally to England and America, and is made into carriage varnish. The best quality, however, is like clouded amber, and is, in fact, used for the mouthpieces of pipes and ornaments for ladies. It is brittle, translucent, and gives off a fragrant odour when heated. The following is the result of an examination by Mr. J. Fuller: "The Gum is a resin of sp. gr. 1.05. It is partly soluble in cold alcohol. The residue does not dissolve on heating, but appears to take a quantity of alcohol into itself, forming a viscous mass. This becomes brittle on heating, or on exposure to the air. The alcoholic solution forms a very clear varnish. The Gum melts at about 320° Fah.: the residuum requires a higher point for fusion. Forty-two per cent. of the Gum is insoluble in alcohol. The Gum is soluble in turpentine and the oils forming varnishes. It is only slightly acted on by caustic soda saponifying slowly." A lively discussion, as to the manner in which the Gum got into the ground, concluded the evening.

ENTOMOLOGICAL SECTION.

DURING the past summer, owing principally to the exceptionally wet season, only one out-door excursion was taken, on May 11th, to Weston-super-Mare, the day being very unfavourable; the captures made were very few and principally common sand-hill species. Two other excursions were planned, but bad weather prevented their being carried out.

Many interesting species, both British and exotic, have been exhibited during the year at the indoor meetings of the section. Among the British lepidoptera may be mentioned *Deilephila galii*, *Platypteryx sicula*, *Stauropus fagi*, *Dianthecia albimacula*, *Nascia cilialis*, *Mellissoblaptes cephalonica*, *&c.*, *&c.* Among Coleoptera, the best capture in the neighbourhood for the season, was one of a number of specimens of *Eros minutus*, by Messrs. E. C. Rye and Mc Lachlan, during the visit of the British Association; others were afterwards captured by members of the Entomological Section. A number of this pretty little rarity were captured some twelve years since by Mr. Edwyn Reed, also at Leigh Woods, but no additional specimens had occurred until Messrs. Rye and Mc Lachlan re-discovered it.

In August, Mr. J. T. H. Preston captured a specimen of *Euperia fulvago* at Fishponds, and exhibited it at the October Meeting of the Section—this capture is interesting in being the only recorded occurrence of this fine species not only in the Bristol District, but also in the West of England.

At the October Meeting of the Section, Mr. A. E. Hudd read the following note on *Solenobia pomonæ* and *Xymastodoma melanella.*

"Some years since, in 1869, Mr. Harding published in the Entomologists' Monthly Magazine, Vol. VI., pp. 91-93, some notes on these species, in which, from the fact of having bred both forms from cases collected from the same trees, it was suggested that probably both forms were in reality only one species; and, that in fact, what had previously been known in England as *Solenobia Pomonæ* was, in reality, only an apterous form of the female of *Xymastodoma melanella.*

This startling theory naturally caused great surprise at the time among Microlepidopterists; but, although more than six years have since elapsed, no one has, so far, attempted any explanation of the facts contained in Mr. Harding's paper until quite lately, when Mr. Boyd, of Cheshunt, has taken the matter in hand. This gentleman has kindly forwarded to me a paper on the subject which he has prepared for publication in the next number of the magazine, in which paper I think he has quite proved that the two forms are not of the same species.

The apterous females belong to a species of Solenobia which is at present only known in that form; they emerge from cases differing from those of X. melanella, and in emerging leave their pupa skins inside the case which they never entirely forsake during their short lives, resting generally with their long ovipostors concealed in the mouths of their larva cases.

Both sexes of X. melanella on the other hand, not only emerge from their cases, but draw out their pupa skins with them, the wings of the female being as fully developed as those of the male but rather narrower.

Cases and images of both forms were exhibited from Mr. Boyd.

Mr. Harding in reply said, the subject brought forward by Mr. Hudd was one surrounded by difficulties, and that much could be said on both sides of the question. He had long been aware that some of the cases were more or less three sided, while others, even cone shaped, and even if it was conceded that the more angular cases always produced the winged form, while the more cone shaped ones produced the apterous female, still nothing could be proved conclusively from this—the great difference in the forms to be produced would quite explain the slight differences in the cases.

With respect to the other point which Mr. Boyd and Mr. Hudd seemed to consider quite conclusive, viz., that the winged forms in emerging from their cases dragged out with them their pupa skin—nothing conclusive can be proved from this fact if all the circumstances are taken into account. In the one case you have a fully developed, vigorous insect, and in its struggles to get free, the pupa skin is dragged out of the case either fully or in part. On the other hand, the apterous form is most sluggish, and is not only quite wingless, but almost legless: the wonder to me is not that it does not drag out its pupa skin, but that it is able to emerge at all.

There is now no question at all that these singular apterous females have in themselves the power of re-production for several generations at least; but I certainly am not prepared to admit that they have the power of continuously re-producing themselves—a conclusion to which we seem to be driven if S. Pomonœ is a true species—since I first discovered this species, some fourteen or fifteen years ago, I think I may say, positively, that no male form has appeared, that is if Pomonœ is not a form of Melanella. It is a question full of interest; and, now, that Mr. Boyd has again drawn attention to the matter, it is to be hoped that it will not again be lost sight of until the singular economy of these insects is conclusively worked out.

At the December Meeting of this Section, the Chairman, Mr. S. Barton, called the attention of the members to the lamented death of Mr. Sanders, and a motion was carried expressing the sorrow of the Entomological Section at the great loss sustained by the death of the President.

Mr. W. H. Grigg then read some further notes on *Platypteryx Sicula*, and reported the capture of three additional specimens on the 23rd, 24th, and 26th of June. He also mentioned, as of greater interest, the fact of the larva of this insect having been discovered; one specimen of the caterpillar was beaten from lime by Mr. Thomas, on September 11th, and was at once forwarded to Mr. Buckler for figuring, and this had been satisfactorily accomplished.

GEOLOGICAL SECTION.

FEBRUARY 10th, 1875.—The Annual Meeting of the Section; the President and Secretary were re-elected. Mr. E. Tawney proposed that instead of giving a guinea to the Parent Library, some geological work should be purchased by the Section in future and presented. This was the only evening Meeting of the Section, such geological papers as were produced by members having been taken to the General Meetings.

May 18th, 1875.—The first excursion of the Section was on Whit-Tuesday. As usual, the whole of the day was devoted to this purpose, and the goal was the neighbourhood of Ilminster. The party, consisting of nineteen, left by the 8.10 train, the manager of the Bristol and Exeter Railway having courteously placed a broad-guage saloon carriage at their disposal. On arriving at Ilminster, vehicles were in attendance in order to take them over the ground more rapidly. The first sections visited were those of Herne Hill, where the Upper and Middle Lias is well seen; driving thence through the villages of Donyatt and Seamills they reached the Moolham Quarries, where a further search for fossils was made. From here the road was taken through Kingstone to Shepton Beauchamp and through a charming country overlooking Seavington, rich in orchards and picturesque lanes. Thence through the village of Barrington, with its interesting church, to Barrington Hill, which was ascended on foot; after the quarries there had been well explored, the carriages were regained, and return was made through Packington to Ilminster. A halt was made at the hotel for dinner; the church was afterwards visited, and finally departure made for the train (6.45). The weather was all that could be desired, and in every way the expedition was most successful.

Owing to the visit of the British Association in August last, and to the preparations necessary for it, the ordinary excursions were a little interfered with. Consequently the following was the only other one of this Section:—

September 29th, 1875.—A small party started by the one o'clock train for Yate; they walked by road to Yate-rocks through "Goose Green." The Carboniferous Limestone was found exposed in quarries with very pronounced vertical joints, always simulating bedding, so regular was the division into masses of a foot thick or so; the joints were E and W; the bedding was at an angle of 15°—20°. A curiously laminated condition of the Magnesian Limestone was found in blocks reposing against the Carboniferous Limestone. Barytes is said to be worked in the red ground out in the valley below.

Obituary.

Our lamented President, the late W. Sanders, F.R.S., F.G.S., who died Nov. 12th, 1875, was born January 12th, 1799.

From early years he took to the study of mineralogy and geology, and for about 50 years he superintended these departments in the Bristol Institution. His name appears already in the first few years after its foundation, (1824, &c.,) as a donor to the collections, and 1827 he took the Hon. Secretaryship of the Museum sub-committee, and continued as such to direct the Museum affairs till 1856; when there being no longer any Curator, the title was made for him of Hon. Curator. On the amalgamation of the "Institution of the advancement of Literature, Science and Art," with the "Bristol Library Society" in 1871, he became a Vice-President of the joint Society, as well as Hon. Curator of the Museum, and continued to give the greater part of his time to working for it and watching over its interests.

In 1845 we find him occupying the place of joint Secretary of the "Philosophical Society" which used to meet at the Institution for their evening Meetings, and this office he kept till the Society gradually died out, and its place was taken by the Naturalists' Society, the field-meetings of which were more in harmony with the active spirit of the age. Of the latter Society he was one of the originators, and has been annually re-elected President from the commencement.

His earliest published work seems to have been a short pamphlet on the crystalline form of Celestine from Pyle Hill, Bristol, worked out according to Brook's method which was then in vogue.

During the making of the Great Western and Bristol and Exeter Railways, he surveyed the whole of the cuttings between Bath and Bristol, and thence to Taunton, laying down to scale the whole of the different beds, showing their true dips, thickness, &c., copies of this manuscript section are preserved in the Mining Record Office.

Travellers on the Great Western Railway may notice near one of the tunnels close to this city, a large spherical mass of ferruginous rock placed on a pedestal of masonry; this was there placed at Mr. Sanders' expense, he having obtained permission from the engineers to preserve this concretion which came out of the Pennant Sandstone.

His intimate knowledge of the geology of his native town, was early of use to his fellow citizens. In the Parliamentary enquiry into the health of Towns Commission in relation to visitations of cholera he assisted Sir H. De La Beche, contributing the coloured geological map of Bristol and a horizontal Section through Bristol and Clifton showing the geological structure of the ground on which the city is built. This was printed in the "appendix to the second report of the Royal Commissioners of enquiry into the state of large towns and populous districts," (1844-5,) together with some geological details as is there acknowledged (*ibid.* Report on Sanitary Condition of Bristol, pp. 8-9.) Subsequently he contributed similar matter but somewhat extended, to the "Report to the General Board of Health on a preliminary enquiry into the sewerage, drainage, and supply of water, and the Sanitary condition of its inhabitants," by G. T. Clark, superintending Inspector for Bristol, (London, 1850.) For this work four horizontal Sections were run through the town, geologically colored, and the geological map as drawn up by him again added.

The following papers were contributed by him to meetings of the British Association:—In the year 1840, "Account of a Raised Sea-beach at Woodspring Hill, near Bristol." In 1841, "Notices of Sections between Bristol and Bath, a distance of twelve miles, prepared by direction of a Committee of the British Association." In 1846, "On Railway Sections on the line of the Great Western Railway between Bristol and Taunton." In 1849, "On the Age of the Saurians, named Thecodontosaurus and Palæosaurus."

He early formed a friendship with the late Professor J. Phillips, and accompanied him and Sir H. De la Beche during a part of their work in Devonshire, about 1835. In 1844 he went to Switzerland to renew his acquaintance with Agassiz and study glacial phenomena; he stayed some days at the Grimsel Hospice in company with Professor Desor. During the same trip he met Professor J. Forbes on the Mer de Glace, and had the advantage of seeing the results of his observations.

We have now to mention his *Opus Magnum*—what may be almost said to have been the work of a lifetime—viz., his large geological map of the Bristol coalfields. He began a geological map of the environs of Bristol, perhaps about 1835; he seems to have worked originally on large-scale maps, transcripts of parish ones, and, as Sir H. De la Beche was soon after that time working for the Government Geological Survey in the district, he seems to have copied the boundary lines on the one inch ordnance map and presented his results to the National Survey. His name appears accordingly on the Bristol sheet of the Government map. His friend, Sir H. De la Beche, however, persuaded him not to abandon his work on the large scale, which admits of much greater accuracy of delineation, but to continue it and publish it. This object he seems to have kept before him, and after more than twenty years of work he finally accomplished it; the large map of the Bristol coalfields, on a scale of four inches to the mile, was finished in 1862. It contains over 720 square miles of country, reaching from Wells on the S., to Berkeley on the N., and Bath on the E.; the geological lines are all from his own surveys, on which he bestowed most scrupulous care, and it may be truly said that no single amateur has ever produced such a work on his own resources. The topographical basis of the map too had to be reduced by collating some hundred parish maps of many different scales; this was done at his own cost and under his own immediate revision. Topographically considered even, the map is a work of great usefulness.

About 1863 his summer trip was spent in the Snowdon district, and he has more than once related to us how, when he was hammering out fossils near the top of Snowdon, he was accosted by the Duke of Edinburgh, who happened to be making the ascent, and asked him what he was looking for, and whom he at once initiated into the delights of his own favourite science.

In 1864 he was elected a Fellow of the Royal Society of London, in recognition of his valuable geological surveys.

His discoveries and expositions to the Geological Section of our Society will be in the remembrance of many.

In 1852 he was elected one of the Trustees of the Bristol Charities, and as such he continued to serve till his resignation in the summer of 1875 through failing health; he devoted himself with great zeal to the work, taking especial interest in the educational foundations.

In 1865 he became a Director of the Bristol Water Works Company, and continued one till the end. From 1838 he had been one of the Directors of the Savings' Bank, of which his father was one of the chief originators.

As a private friend his loss is mourned by many. To local students of science it is no less a grievous one. One trait of his character was his great modesty; although his local geological knowlege was so profound, he always listened with interest to the questions of beginners, and made them almost feel that they were supplying him with information, while he was gradually removing their difficulties. Other pages of this volume bear witness to the sorrow of the members at his decease.

E. B. T.

ERRATA TO VOL. I.

Page 11, line 12, column 2. For "reticulata" read "sub-reticulata"
..... 13, ... 3. For "in the state of," read "in the present state of."
...... 23, ... 11. For "Murchisoni," read "Murchisonæ."
.. ... 42, ... 13. For "greatest height," read "greatest breadth."
...... 97, ... 11, from base. For "acerasum," read "acerosum."
...... 101, ... 2 and 4 from base. For "Tetnemorus," read "Tetmemorus."
...... 110, ... 15. For "Combrash," read "Cornbrash."
.... 16. For "Finest," read "Forest."
...... 111, ... 19. For "realy," read "really."
...... 127, .. 8. For "Arancida," read "Araneida."
...... 138, ... 7. For "Vestebra," read "Vertebra."
...... 139, ... 7. For "Aricula" read "*Avicula.*"
.... 15. For "unless the circumstances," read "unless these circumstances."
...... 140, ... 4 from base. For "at the top," read "at the base."
On plates 4 and 5, read "Vol. I," for "Vol. II."
...... 147, ... 13 from bottom. For "461, 22," read "vol. 161, p. 511."
...... 148, ... 6 from bottom. For "have," read "has."
...... 170, ... 5. For "*Spiriferini,*" read "*Spiriferina.*"
...... 170, ... 6. For "*Gy*, read "*Gry.*"
...... 171, ... 7 from bottom. For "position," read "condition."
...... 172, ... 18. For "*variablis,*" read "*variabilis.*"
...... 172, ... 10 from bottom. For "clayshell," read "clay-shale."
...... 178, ... 12 from bottom. For "*Pleuratomaria,*" read "*Pleurotomaria.*"
...... 182, ... 6 from bottom. For "5″ 6‴" read "5′ 6″ "
...... 184, ... 7 from bottom. For "remaked," read "remarked."
..... 187, ... 13. For "phosphatical," read "phosphatised."
...... 194, ... 16. For "*ven lencophæa,*" read "*var leucophæa.*"
...... 199, ... 2. For "Tissidens," read "Fissidens."
...... 206, ... 21. For "problems,' read "problem."
...... 210, ... 32. Cancel the whole of the line.
...... 210, ... 33. For "the," read "The."
...... 211, ... 5. For "lineal," read "linear."
...... 211, ... 12. Ditto ditto
...... 211, ... 6. For "sum," "sum," read "product," "sine."

ERRATA.—*Continued.*

Page 213, line	1	For sentence beginning "on the other hand," read "on the one hand, there must be taken into account the changing and constantly lessening divergence of pencils of large apertures after entering the objective: on the other hand, the opposite condition, &c."
...... 216, ...	17.	For "in," read "on."
...... 217, ...	4.	For "two first," read "first two."
...... 217, ...	21.	For "every improvement," read "every later improvement," and cancel "since."
...... 218, ...	7.	For "affected," read "effected."
...... 219, ...	27.	For "as," read "and."
...... 221, ...	16.	For "in the," read "IX. In the."
...... 222, ...		In note, two lines from bottom, for "Roberts'" read "Nobert's."
...... 228, ...	9.	For "refracted," read "refrangible."
...... 229, ...	28.	For "thing," read "things."
...... 230, ...	12.	For "So long as the angle, &c." read "As long as the size of aperture remains so large that, &c."
...... 230, ...	29.	For "definite kind," read "prescribed form."
...... 231, ...	8.	For "illuminations," read "illumination."
...... 234, ...	19.	For "surface," read "surfaces."
...... 240, ...	11.	For "alteration," read "alternation."
...... 255, ...	18.	Cancel "does."
...... 246, ...	27.	For "content," read "contents."
...... 250, ...	1.	For "operation," read "observation."
...... 251, ...	18.	For "From the point, &c." read "XXIII. From the point, &c."
...... 253, ...	2.	For "content," read "contents."
...... 253, ...	5.	For "in," read "or."
...... 254, ...	20.	For "objective," read "objectives."
...... 255, ...	32.	For "pencil," read "pencils."
. ... 255, ...	34.	For "condition," read "conditions."
...... 260, ...	11.	For "partially," read "potentially."
...... 261, ...	23.	For "condensors," read "condensers."
...... 264, ...	8.	For "sound," read "sand."
...... 265, ...	7 from bottom.	For "Holapella," read "Holopella."
...... 271, ...	8.	For "Limestone," read "sandstone."
...... 277, ...	14.	For "PALMOBRANCHIATA," read "PULMOBRANCHIATA."
...... 301, ...	14.	For "*Ælcistes,*" read "*Æcistes.*"
...... 304, ...	5 lines from bottom.	For "*Fontanalis,*" read "*Fontinalis*"
...... 306. ...	10 from bottom.	For "*amygdalima,*" read "*amygdalina.*"
...... 309, ...	9.	For "*albipunta,*" read "*albipuncta.*"
...... 189, ...	column 1, line 12 from base.	For "Terebratuta," read "Terebratula."
...... 319, ...	column 1, line 12.	For "crinisria," read "crinistria."
...... 322, ...	column 2, line 12.	For "covonata," read "coronata."
....	column 2, line 9 from base.	For "oralis," read "ovalis."
...... 333, ...	column 2, line 7 from base.	For "canalienlata," read "canaliculata."
...... 338, ...	9.	For "seam," read "seams."
...... 348, ...	7.	For "centnry," read "century."

ERRATA.—*Continued.*

Page 352, line 10 and 11. For " Bex Diablercts," read "Bex Diablerets."
...... 353, ... 8. For " chose," read " choose."
...... 375, ... 18. For " L. rusticola," read " S. rusticola."
...... 384, ... 8 from base. For " discovery fossils." read "discovery of fossils."
...... 471 ... 20. For " forea," read "fovea."
...... 482 ... last line. For "nch," read "inch."

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DIGEST OF THE

LIBRARY REGULATIONS.

No book shall be taken from the Library without the record of the Librarian.

No person shall be allowed to retain more than five volumes at any one time, unless by special vote of the Council.

Books may be kept out one calendar month; no longer without renewal, and renewal may not be granted more than twice.

A fine of five cents per day incurred for every volume not returned within the time specified by the rules.

The Librarian may demand the return of a book after the expiration of ten days from the date of borrowing.

Certain books, so designated, cannot be taken from the Library without special permission.

All books must be returned at least two weeks previous to the Annual Meeting.

Persons are responsible for all injury or loss of books charged to their name.