WATER SUPPLY

BALFOUR BROWNE

&M.&Co.

WATER SUPPLY.

WATER SUPPLY.

BY

J. H. BALFOUR BROWNE,

Barrister at Law; Registrar to the Railway Commissioners; Author of "The Compulsory Purchase of Company's Undertakings by Corporations;" "Borough Extension;" "The Law of Rating;" "The Law of Carriers," &c.

London:

MACMILLAN AND CO.

1880.

LONDON:
R. CLAY, SONS, AND TAYLOR,
BREAD STREET HILL.

WATER SUPPLY.

In most cases the first words of an essay are an excuse for its being written; but we cannot think that an honest endeavour to collect and place on record any facts or important opinions respecting Water Supply can require an apology. The subject is one of paramount importance. It is one which has not only a close connection with prophylactic medicine, but with sanitary legislation. In its medical aspect it has become more important as the science of sanitation has become more certain; and in these days, when legislation is willing to follow closely on the heels of science, instead of taking its own free and ignorant way, as it used to do, it is every day becoming more vital as a question of practical law-making. Water, which used to be the luxury of the few, has now become the necessity of the many. Its importance as an agent of health has been more thoroughly appreciated in recent years, and uses are made of it to-day which would only have been shuddered at by our less cleanly ancestors.

Formerly men were left to secure water or do without it, as they chose, and no duty was thrown upon any administrative authority to see that those whose interests they had to watch over had a supply.[1] The Public Health Acts of 1848 and 1875, authorised local authorities to provide their districts with water in case there was no existing supply in the hands of a Parliamentary company, and still more recently an Act of Parliament[2] has made it incumbent upon every Rural Sanitary Authority, "to see that every occupied dwelling-house within their district has within a reasonable distance an available supply of wholesome water sufficient for the consumption and use for domestic purposes of the inmates of the house." They are, too, to see that no house is built within their district without an available source of supply being secured to it, and the Local Government Board are empowered by Section 11 of that Act, to invest any Urban Sanitary Authority with the powers or duties given to or imposed upon a Rural Sanitary Authority under that Act.

At the same time that the necessity of a supply of

[1] The amount of benefit which has resulted to public health from the execution in towns of drainage works and works for the supply of water may be seen from an instructive table which is given in one of the Reports of the Medical Officer of the Privy Council. Dr. Buchanan, who seems to have made the investigation, concludes his report by pointing out that the progress made by the inhabitants of most of the towns in decency, cleanliness, self-respect, and morality was at least as striking as the improvement in their health measured by the morality returns, an observation which bears out the view we have long held,—that water is a great moral agent as well as a great physician.

[2] Public Health (Water) Act, 1878 (41 & 42 Vict. c. 25, sec. 3).

water has become a recognised fact in the public mind, the necessity for the selection of pure sources of supply, and the careful scrutiny of our means of distribution, have become more generally admitted. It has been said that every virtue has its attendant vice, and it would seem that every sanitary boon has its attendant morbific influence. A refuse pipe, as generally constructed, while it carries away the filth of a household, makes its bedrooms coterminous with the deadly purlieus of a drain system. A water supply which gives us a beverage which may sparkle on our tables, may be the means of conveying to us the seeds of deadly disease. All these considerations would seem to be sufficient reason for discussing some questions relating to water supply with what care we can bestow, and with the light of such authorities as we may be in a position to command.

It is scarcely necessary to point out that we have to look to rain for all the water we can utilise for any purpose. The clouds drink from the sea and the moist land, and return their moisture here and there in the form of rain or snow. But without going thus far back into the genealogy of water, we may say that we depend for our supplies upon the water which runs from the surface suddenly after rain has fallen, which we call surface water; upon rivers, which are fed by this surface water, by water which has been absorbed by the earth and is given out again in the form of springs, and by water which was caught in hollows or spongy places, and which wells out from these slowly; and thirdly, upon springs themselves; and we may either find these trysting with us at the surface, or may have to go very far into the bowels of the earth to meet them. These three, then, are the sources of all water supplies.

As to the first, surface water. The question whether surface water is good for a supply, cannot be answered unless there is a knowledge of the surface from which it flows. So far as we know, rain water when it falls is pure water, and although we cannot think that it can pass free of taint through the thick atmospheres of some of our towns, it is certain that when it falls it is free from all living vegetable or animal matters. We do not propose to consider the question of the collection of surface water in shallow wells. There are few or no apologists for such a supply in these days. Even small towns are discovering the evils of such a system, and in large towns it has happily long been condemned, and is very nearly discarded. Even in the country there are serious objections to the existing shallow-well system of supply. Nearness to the house has been the great object of desire, and in securing a well in close proximity to the back entrance, people have secured to it ready access to all the filth, refuse, and contamination of the household. But the consideration of this matter scarcely falls within the scope of our present purpose. If the rain falls upon a clean gathering ground of moorland it can safely be used for domestic, and is certain to be used with advantage for manufacturing, purposes. Most of our great supplies are simply surface waters collected in natural or artificial reservoirs from clean gathering grounds. The present supply of Manchester from the Longdendale Valley, and the authorised supply of the same town from Thirlmere, are examples of such sources of supply. But the illustrations of this means of supply are innumerable. Sheffield is supplied from impounding reservoirs on the upper waters of the Don; Halifax by similar works upon tributaries of the Calder; Dewsbury from similar reservoirs at Dunford Bridge; while Glasgow, as is well known, is supplied from that natural reservoir, Loch Katrine. It matters not, it would seem, in a sanitary point of view, how quickly the water may run off the ground as long as the surface is a clean one. Of course the existence of agricultural land highly cultivated and manured, in the catchment area which supplies a reservoir, would be a serious evil when the necessities of a town are had regard to. The best of all gathering grounds is a clean grouse moor upon a high elevation; for, as it has been said, "it is the hill tops which make the rivers." The existence of lead-mines, too, above the source of supply might be a disadvantage, and may have been one reason why Manchester ultimately determined upon going to Thirlmere instead of to Ulswater, although we suspect the shortness of the tunnel in the former case as compared with that in the latter, had more to do with the engineer's recommendation. However, the question of the washings of the lead at lead-mines, or "hush," as it is locally called, was much discussed in the Stockton and Middlesborough cases of 1875 and 1876, and is certainly a matter to be had regard to in reference to the selection of a site for supply reservoirs. Of course in the selection of a site for such a reservoir the engineer must be guided a good deal, not only by the nature of the gathering ground, but by the way that the contours and the geological formations lend themselves to the construction of such works. In the Wakefield scheme of this session (1880), the engineer could only find one convenient site in the Rishworth Valley, that at Green Withins, and had to carry a large portion of the water forward by means of a conduit to the Ringstone reservoir, and even then had to forward about 300,000,000 gallons to another reservoir close to the district of supply, at Ardsley. Steep gathering grounds are perhaps the best for the water; for it runs off rapidly without getting stained by peat; but they often make the construction of reservoirs, without dangerously high embankments, impossible.

Formerly it was the constant custom for companies to appropriate the river water which was flowing past the towns they desired to supply, and to pump that up into their service reservoirs. More recently, however, the collection of hill-surface waters in impounding reservoirs has been the favourite means of water supply. There is a great deal to be said in favour of such schemes. The sooner the consumers get the water after it has left the clouds, the softer it will be, and most of our large towns, depending much upon their trades, have a paramount interest in securing soft water. When the Wakefield Water Bill of 1876 was before a Committee of the House of Commons, one witness said that if he could use rain water for his worsted manufacture, for dyeing and scouring, instead of the Wath water, which it was proposed to supply under the Bill, and which was over 15° of hardness, he would save £1000 a year,[1] and the action of the town of Wakefield in the matter of its water supply shows the importance, to manufacturing districts, of a few degrees of hardness. In 1880, the Corporation of Wakefield promoted a Bill for the supply of soft water from Rishworth, in the valley of the Ryburn, a scheme which was estimated to cost £276,000; having in 1876 purchased the undertaking of the Water Company—which had, up till that year, drawn its water for the supply of the town from the River Calder, at Stanley Ferry, and which was in that year authorised to take its supply from the Oaks rock at the Wath Main Colliery, in the valley of the Dearn—for £208,000; with the view, as the witnesses for the Bill of 1880 said, of preventing the introduction of a supply of hard water into Wakefield. The water from Rishworth, on the other hand, which has only 2° of hardness, would, it was said, enable Wakefield to compete with various towns in the industries which are so successfully carried on in the West Riding of Yorkshire. Two hundred and eight thousand pounds is a considerable sum to pay to get rid of a hard water supply; but the sacrifices Wakefield was willing to make to secure a soft water, shows the importance of such a supply to manufacturing interests.

That, then, was one reason why such schemes as those

[1] Wakefield Water, 1876; Evidence of Mr. Henry Lee, p. 280, Question 4766.

we have been referring to were favoured, but there were others. It seems certain that it is better for a river to have moderate floods than to have immoderate floods. As we remarked elsewhere, "For almost all purposes floods are useless. They are useless to the mill-owner, who uses water for power; they are useless to the steam mill-owner, who only uses small quantities of water for his steam purposes; they are useless to the sanitary authorities, for while they scour the bed of the river, being beyond bounds they deposit the *débris* upon the banks, where it is slowly and offensively oxidised. Consequently the idea that these floods might be stored in reservoirs in valleys, near the sources of the stream, that their force and damage might be mitigated by impounding reservoirs, that the mill-owners and steam mill-owners might secure from the water so stored a certain amount when there was little or none in the river, was in accordance with the best economy. Such a proceeding would be a benefaction to every one who was interested in the water of the river, as it would take from them that of which they had no need and which they could not use, and it would supply them with water when it would be most valuable to them, when their need was greatest, and when their wants could not be supplied except by some such expedient."[1] What every one wants is an equal flow and occasional freshets, rather than a dribble at one period of the year and floods which exceed the minimum flow by

[1] *Compulsory Purchase of Companies' Undertakings*, p. 24.

300 times its volume at another.[1] Now a town or a company which goes to a moorland at the head of a river and places an embankment across the valley and impounds the streams and surface waters, confers this benefit on the inhabitants of the valley below. The high floods are caught in the reservoir, and the storm waters which do run down the valley do less damage. As we have said, it is not only a benefit to the inhabitants, but it is an admitted advantage to the mill-owners on the stream to have the flow of the river equalised. The flow is equalised first by the mitigation of the violence and volume of the floods, and second by the payment to the river, at such hours as may be most convenient to the mill-owner, and as may be agreed upon, of a certain quantity of compensation water. The amount to be given as compensation to the stream is now established by long practice to be one-third of the available rainfall, while in respect of this payment the company or corporation is allowed to take the remaining two-thirds for town supply. Nice questions consequently arise as to the probable rainfall in any particular gathering ground, and in such cases the rainfall statistics of Mr. G. J. Symonds, F.R.S., who has during the last twenty years organised a careful system of observations at more than 2000 stations in the United Kingdom, and who has made most excellent use of the information thus obtained; and the great

[1] See evidence of Mr. Hawkesley, C.E., in support of the Wakefield Water Bill, 1874; Commons, p. 63, Question 1046; and in the evidence in the House of Lords.

experience of Mr. James Glaisher, F.R.S., are invaluable assistants. It was before these accurate means of determining the probable rainfall were available, that serious mistakes in the adjustment of the proportions to be given to compensation and supply, were made. Thus Manchester and Liverpool, having given a much larger compensation than they could afford, "They were obliged to buy up their own water to a very considerable extent at a very large expense, so as to recover that which ought never to have been given."[1] A similar error, too, was made in the case of Dewsbury, where a much larger amount had under their Act of 1853 to be given in compensation, than could be given consistently with a proper supply to the districts whose wants were the cause of the construction of the works.[2]

An objection which is sometimes urged against works of the kind we are considering, is that a reservoir containing three or four hundred millions of gallons of water may burst, as the Dale Dyke reservoir—one of the Sheffield reservoirs,—did in fact burst, and such an accident would of course be a terrible calamity to the inhabitants of the valley below. But in the first place, it is certain that any competent engineer can avoid the mistakes which led to that catastrophe. There are too, provisions in the Waterworks Clauses Act to ensure

[1] Wakefield Water Bill, 1874; Lords, Evidence of Mr. Hawkesley, p. 302, Question 4903.

[2] See *Compulsory Purchase of Companies' Undertakings*, p. 39.

the safety of such works.[1] In the Stockton and Middlesborough Corporations' Water Bill, 1876, in which a question as to the safety or unsafety of the Grassholm reservoir was raised—the site of which it was suggested was ill chosen, because the boulder clay in which the puddle trench was to be placed was not continuous down to the limestone, but had between it and the rock a stratum of running sand—the experienced engineers for the opposition looked upon this question as one mainly, if not wholly, affecting only the estimates, and not the possibility of making a stable embankment.[2] There is thus, we may say, a remarkable preponderance of opinion in favour of the schemes which have for their object the collection and utilisation of the hill surface waters for town purposes. A glance at a "large map" of England will show that very few of the valleys in the "backbone of the country," as the Pennine range has been called, are unappropriated by some town or company, and unoccupied by some large reservoir; and in the inquiry into the Manchester Corporation Water (Thirlmere) Bill, 1878, it was proved to the satisfaction of the Select Committee that there was no suitable and unappropriated gathering ground nearer to Manchester than that afforded by the Lake District, which is over 100 miles off by the line of pipes.

[1] Waterworks Clauses Act, 1863 (26 & 27 Vict. c. 93, sections 3–11.)

[2] Stockton and Middlesborough Corporations' Bill, 1876; Lords, Evidence of Mr. Hawkesley, p. 597, Question 93.

Rivers.

Passing from that first source of supply, for we need not mention other means of utilising surface water, we may now mention the second source of water supply, viz. rivers. Of course the drawing of water from rivers suggested itself in early times as the cheapest and readiest means of supply. The water was sent to one for one's use, and hence, in very many cases where the question of town supply became one of importance, the rivers which ran close by were chosen as a source of supply. Of course it must be remembered that rivers, or the streams which form the head-waters of rivers, are taken into the impounding reservoirs we have been referring to, just as they fall into the natural reservoirs of Thirlmere or Loch Katrine; but they are rivers which are not used for traffic, they are rivers which have not received the drainage of thousands of acres of cultivated and manured land, they are rivers—and this is one of the most important points—above the sources of human pollution, rivers to which the great duty of scavengering a country has not been intrusted. When towns first went to the rivers that ran past them for their water supplies, there might be little reason to object to them on sanitary grounds. They ran clear, and fish swam in them. That is the evidence with reference to the Calder, which was adopted as a source of supply by Wakefield in 1839. But now its water is black, and can be used as ink,[1] and it is described by those who know it best as nothing but an open sewer.[2]

So it was with the Tees when the Stockton and Middlesborough Water Company obtained Parliamentary permission to pump water from that river at Tees Cottage, near Darlington, in 1851. And so with the Wear, when the Durham Water Company began, some thirty-two years ago, to pump water from it at Houghall. But in a very few years, in an industrial country like ours, rivers change their character, and the rivers referred to above, ceased to be pure water channels, and have become effluents for the solid and liquid refuse of large districts of country. Under these circumstances it cannot be wondered at that there is a tendency to desert rivers into which sewage, in however small quantities, has been allowed to flow. "Pumping Schemes," says Mr. Mansergh, "where large rivers are the source of supply, are year by year falling more and more into disrepute, on account of the suspicion which naturally attaches to the water." [3]

No doubt, there are at the present time, some chemists who hold strong views in favour of river water. Dr. Meymott Tidy is a consistent advocate of the supply of river water to towns. He gave evidence in favour of the Tees as a source of supply for Stockton

[1] In the Third Report of the Rivers Pollution Commissioners, 1871, there is, at p. 12, a *fac-simile* of a letter written with the water of the River Calder.

[2] Evidence on Wakefield Water Bill, 1880.

[3] *The Thirlmere Water Scheme*, by James Mansergh, C.E., F.G.S. London, 1878, p. 7.

and Middlesborough, of the Severn at Tewkesbury as a supply for Cheltenham, and of the Wear as a supply for Durham, and that although in all these cases, the water proposed to be supplied was taken from the rivers at points below that, at which large populations poured in their sewage. Dr. Tidy's views as to the destruction by oxidation of sewage in such cases, will be considered at greater length in a subsequent part of this essay. Dr. Odling, too, is not averse to river water, even although sewage may have got into it. But we cannot think that either of these distinguished chemists, would differ from the opinion expressed by Dr. Frankland in evidence on the Wakefield Water Company's Bill of 1876, when he said, " Of all sources of water supply, springs and deep wells are to be preferred," [1] or from Dr. Voelcker in his evidence on the Durham Water Bill, 1878, when he said, " River water at the best is a poor water, and not to be compared with spring water, which is always refreshing, and which is clear and unquestionable water." [2] But although they might not differ from such opinions, they are for the most part entirely opposed to Dr. Frankland's view, a view which is entertained by very many other competent authorities, that rivers into which sewage has been allowed to flow are not to be had recourse to as a source of water supply, holding that, notwithstanding the superiority of most spring water, river water, even after it has received a large amount

[1] Wakefield Water Bill, 1876; Evidence, p. 67, Question 975.
[2] Durham Water Bill, 1878, p. 123, Question 1823.

of urban and rural drainage, is a suitable water for the supply of a town. That seems to have been the conclusion at which the Duke of Richmond's Commission on Water Supply, which reported in 1869, arrived, and it is a conclusion with which, as we have seen, many competent authorities are in accord. The opinion of that Commission may be taken to have been, that the Thames was not at that time an improper source of supply for London, although it had received, above the water company's intake, the sewage of nearly a million people.

But although scientific opinions differ thus widely as to the expediency of having recourse to such rivers as a source of supply—an aspect of the question which will have to be examined more minutely when we speak of the quality of water—public opinion seems to be adverse to the adoption of such sources, if we may infer public opinion from the action of Parliament in several well-known cases. And first we may remark that the very frequency of gravitation schemes—schemes for the supply of water from impounding reservoirs in hill countries—of well-pumping and collection of spring schemes, gives us a fair means of estimating the direction of engineering opinion in this respect. We have too, referred to the opinion of Mr. Mansergh, an engineer of ability and experience. But, quite apart from that indirect evidence, we would refer briefly to one or two cases which bear out our view on this subject.

In 1875, the Stockton and Middlesborough Waterworks Company—which had in 1851 been incorporated by Act of Parliament, and been authorised to pump water from the River Tees, but which had in 1864 been restricted as to the amount of water it might so pump, the limit being 60,000,000 gallons a week—applied to Parliament to repeal that restriction. The population of the district of supply had enormously increased. The number of iron works, which were largely dependent on the Company for their water supply, had increased in a similar proportion. Indeed no district had been more prosperous, in none had trade advanced with such rapidity. The evidence of the Company in 1875, was that they had been pumping more than their maximum, and that if they were not allowed to take more water from the Tees, the trade of that important district must be brought to a standstill. The Bill was opposed, and the objection which was urged by the corporations of these two towns and by persons and public bodies interested in the river, was that the Tees water was not a proper water to be supplied for domestic purposes, that a population of from 10,000 to 12,000 was situate in the watershed above the Company's intake, and that the drainage of that population —in which the town of Barnard Castle, containing from 4000 to 5000 inhabitants, was included—got into the stream. The inquiry was a long and costly one, and the evidence adduced on behalf of the promoters was, that the chemical analysis showed that the water was a wholesome water; that although sewage did in small quantities get into the Tees, chiefly at Barnard Castle, it was entirely got rid of and destroyed before the water reached the Company's intake at Tees Cottage, which was seventeen miles by river from the outfall sewer of that little town. On the other hand, the opponents endeavoured to show that although the sewage might be got rid of by oxidation in a run of that distance, which was extremely improbable, still diseases were carried by means of water which chemical analysis could not ascertain to be unwholesome, and that an epidemic of cholera or typhoid fever might be conveyed by the river, and subsequently by the Company's mains, to the district of supply; that the germs of disease were not to be got rid of by oxidation in the same way that ordinary sewage was, and that there was reason to believe, that even ordinary sewage would not be destroyed by a run of seventeen miles down such a stream as the Tees. The result of that inquiry was that the Bill was rejected, in other words the Committee would not sanction the repeal of the restriction, because they disapproved of the Tees as a further source of supply to these towns. In that session, the Company had asked for the total repeal of the restriction imposed in 1864, and had not proposed any substituted limit. In 1876 they promoted a Bill authorising them to pump 30,000,000 gallons a week from the Tees, in addition to the 60,000,000 to which they had been limited by the former Act. But in the same Session (1876), the Corporations of Stockton and Middlesborough promoted a Bill for the purpose of purchasing the undertaking of the Water Company by compulsion; and also authorising them to construct gravitation works on the Rivers Lune and Balder, two of the headwaters of the Tees, for the domestic supply of their district. These Bills came before the same Committee of the House of Commons, and after a very long and patient inquiry, which covered all the ground which had been gone over in 1875, the Company's Bill was rejected, and the Corporations' Bill passed through both Houses and became law, notwithstanding the strenuous opposition of the Water Company. The River Tees then, was condemned by this action of Parliament as a source of towns' supply, although several able chemists said its water was perfectly wholesome.

In 1878, the Cheltenham Waterworks Company, which was, with its then sources, in a position to supply quite an inadequate quantity of water to the town, promoted a Bill for the purpose of supplying Cheltenham with water from the Severn at Tewkesbury. The town of Tewkesbury itself, was at the time supplied with the very water which was now proposed for the supply of Cheltenham. The population in the Severn Valley above Tewkesbury is somewhere about 276,000, and amongst other towns which throw their sewage into that river is the town of Worcester, which contains some 40,000 inhabitants, and whose outfall sewer is about sixteen miles above the proposed intake of the Cheltenham Water Company. The Corporation of Cheltenham opposed this Bill, and under the advice of Mr. Bateman promoted a Bill by which they sought to purchase by compulsion the Company's undertaking, and also to construct works for the further supply of Cheltenham from springs in the Cotswolds. These Bills were referred to the same Committee of the House of Commons. The evidence was very conflicting. The condition of the Severn at Tewkesbury, was spoken of in very disparaging terms. There was no dispute about the fact that the river was the means of carrying away large quantities of sewage, that there was a very large river population upon the stream, that the tide backed up the water at Tewkesbury, and that dead animals, even of a large kind, were often seen in the water. But the chemists were called in and said, Whatever goes in at Worcester, the water is very good water when it arrives at Tewkesbury. Thus Dr. Meymott Tidy, speaking from very careful analysis, says the water is "a perfectly wholesome water." And again, in the next answer he says it is "an excellent water."[1] Mr. Crookes, too, speaks of the water as "excellent."[2] Mr. Hawkesley, too, the eminent engineer, says the water is "an excellent water, good for all purposes."[3] On the other hand Dr. Frankland said, "I do not think it is a proper water to be supplied to any town,"[4] and Dr. Alfred Hill and Professor Way, expressed similar opinions. It is unnecessary to dwell longer upon the evidence. The question of oxidation was largely discussed in this case, as in others where the quality of

[1] Cheltenham Water Bill, 1878; Evidence, p. 105, Questions 1415, 1416. [2] *Ibid*, Evidence, p 111, Question 1489.
[3] *Ibid*, Evidence, p. 90, Ques. 1209. [4] *Ibid*, Evidence, p. 116, Ques. 2864.

river water was in question. In the end, the Committee came to the conclusion that the Severn was not a proper source of town supply, for they rejected the Company's Bill and postponed their decision upon that promoted by the Corporation, to see if the parties could arrange for the voluntary sale of the Company's undertaking to the municipal authority. In the end that was done by agreement, and the Corporation Bill for purchase and the supply from the springs on the Cotswolds, was passed into law. In that case the Severn was condemned as a source of supply, as the Tees had been two years before. In the same session of Parliament (1878), the Durham Water Company, which had been incorporated, but not under Act of Parliament, about thirty years before, for the purpose of supplying water to the town of Durham, promoted a Bill to put itself under the General Acts,[1] and to obtain that protection which is extended to companies authorised by Parliament to supply water, under the 52nd Section of the Public Health Act, 1875. The Company also desired to raise further capital to provide additional engine-power and filter beds, with the view of supplying the districts surrounding the city. The Company, it appeared, drew its water from the River Wear at Houghall, and it was shown that the condition of the river at that point had, owing to the opening up of the Durham coal-field and the consequent increase of population in the valley of the Wear, very much deteriorated since the construction of the Company's works. The water-

[1] The Waterworks Clauses Acts, 1847 and 1863.

shed of the river above the point of intake was no doubt a large one, comprising 350 square miles, but the population and other sources of pollution, such as collieries and lead-mines, were also numerous. The population above Houghall was variously estimated at from 130,000 to 200,000, and the town of Bishop Auckland was only thirteen miles higher up the river. The Corporation of Durham opposed this Bill on the ground that the water of the Wear was unfit for domestic supply, and that Parliament should not give its sanction to such an impure source. They called as witnesses Dr. Alfred Hill, Mr. Keats, Dr. Voelcker, and Mr. Spencer, who supported that view by their opinions. On the other hand, Drs. Odling and Tidy and Mr. Crookes, thought the Company's water unimpeachable. There was a good deal of similarity in the evidence given before the Committee on this Bill, and that which had been given before a Committee of the other House upon the Cheltenham Water Bill, earlier in the session. The result too was similar; the Company's Bill was rejected. The River Wear was condemned as a source of supply. Another indication of the bent of public opinion is the action which was taken in the same year, 1878, by the Metropolitan Board of Works, as to the supply of water for London. At present, as most people know, London is supplied by eight companies, and seven of them draw their water from the Rivers Thames and Lea. These companies, by means of steam-power, force 120 million gallons of water a day, either over stand-pipes or into high-service reservoirs, from which it gravitates into the consumers' cisterns. The Thames drains more than two and a half million acres of land, much of which is highly cultivated and loaded with manures—it is the receptacle for the sewage of many large and increasing towns, and, after rain, the river comes down for many days together in such a turbid state that even the large subsiding ponds which have been constructed by the companies, do not always discharge the matter which is held in suspension, or make the water a good colour. These circumstances have led to a somewhat widespread feeling—many persons would call it a prejudice—that the Thames is not a proper source of supply.

In 1878, the Metropolitan Board of Works, acting under the advice of three distinguished engineers, Sir Joseph Bazalgette, Mr. Bramwell, and Mr. Easton, promoted two Bills, one for the purchase of the existing Water Companies, and the other for the supply of potable water to London from deep wells sunk in the chalk at various points in the neighbourhood of the metropolis, from which it was estimated that about sixteen million gallons a day could be obtained. They proposed that this new supply should be distributed through a separate set of mains and service-pipes from those which at present supply, and were in future to continue to supply the Thames water, and that while the existing supply was to be used for washing and other household purposes, the chalk water so supplied was to be used only for drinking and dietetic purposes.

The new supply, being delivered at high pressure, was to be available for the extinction of fires. This scheme, it was estimated, would cost £5,440,000 to carry out. No doubt there were disadvantages connected with this proposal. The difficulty of getting consumers to use the respective waters only for the purposes for which they were intended, was obvious. The expense connected with two parallel systems of distribution would have been great, and both the purchase and supply schemes were ultimately dropped; not, however, before they had cost the Metropolitan Board somewhere about £15,000. We have referred to these schemes and measures with a view of showing that public opinion is strongly adverse to river waters. We have no doubt that other cases might have been referred to, but with all those to which we have referred, we had opportunities of knowledge from our professional connection with the Bills and proposals for Bills which we have discussed. We may, however, strengthen this view by quoting from Mr. Michael's *Address on Health.* No one has a more intimate knowledge of the course of Private Bill legislation than he has acquired in his extensive practice, and he says:—"Apart from all disputes of a technical character, it may now fairly be taken for granted, that the Legislature will not authorise the employment of river water receiving sewage above the intake of a water company, as fit to be used for domestic supply." [1]

[1] *Address on Health, delivered at the Social Science Congress, Cheltenham*, 1878. London, 1879, p. 25.

The Royal Commission on Water Supply, 1869, made two very important recommendations which bear upon the question of supply by gravitation, viz.:— (1) "That no town or district should be allowed to appropriate a source of supply which naturally and geographically belongs to a town or district near to such source unless under special circumstances which justify the appropriation;" and (2) "When any town or district is supplied by a line of conduit from a distance, provision ought to be made for the supply of all places along the line." In reference to the first we may say, that in the Wakefield Water Bill, 1874, a list of twenty-four places drawing their supply from watersheds not their own was put in, and the list could be lengthened now by others, but certainly by one notable exception to the Commissioners' rule, viz.: Manchester, and the supply from Thirlmere. But in that, and we think in most other cases, the second recommendation has been given effect to, and places along the line of the conduit can, in most cases, by petitioning, secure a supply upon equitable terms.[1]

Springs and Deep Wells.

There are many qualities which recommend spring waters. They are clear, sparkling, and palatable, and as a rule contain a smaller percentage of organic matter

[1] See, for list of towns and companies alluded to, Wakefield Water Bill, 1874; Commons, Evidence, p. 69, Question 1078; Lords, p. 298.

than the waters which are taken even from clean gathering grounds.[1] They have, too, this great recommendation, that they are of an equable temperature (about 50° Fahr.), while impounded or river waters are warm when one wishes them to be cool, and cold when one wishes them to have heat. Besides there is a very important consideration in connection with deep well or spring waters. The natural filtration to which these have been subjected, filtration through rocks, makes the water pure without making it flat; but artificial filtration, to which all river and some hill waters have to be subjected, makes the water flat without making it pure. A very competent authority, speaking of river water, says :—"I would not like to depend upon filtration. Filtration may do a great deal, but the more you filter the flatter it gets, and the worse water it becomes."[2] It cannot be doubted, that in many cases much too great reliance has been and is placed on the filtration of water. Filters for waterworks are constructed by forming a vessel or basin, the bottom of which, although nearly level, slopes gently to a centre line, and which is made water-tight by careful puddling. The floor of this basin is then covered with coarse gravel, upon the top of which finer gravel is laid; then comes a layer of slate chips or sea shells, then coarse sand, and on the top of that fine sand. The fine sand

[1] Wakefield Water Bill, 1876; Evidence of Dr. Frankland, p. 67, Question 975. And see Durham Water Bill, 1878; Evidence of Dr. Voelcker, p. 123, Question 1823. See also analysis in appendix, p. 100.

[2] Durham Water Bill, 1878; Evidence of Dr. Voelcker, p. 123. Question 1832.

is the filtering medium proper, and varies in depth in different filters, being usually from twelve to thirty inches in depth, and the top of the sand may be about from four to six feet from the bottom or floor of the filter bed. The water is allowed to flow gently over the sand through which it sinks, leaving its impurities generally in the first three or four inches of the sand, and it is conveyed from the bottom of the filter by tile pipes into the supply pipes or reservoir, as the case may be. Such a filter as we have described is one which filters mechanically; but in some cases, even in large waterworks, the water is passed through thick layers of bicarbonide of iron, which filter not only mechanically and by the attraction of cohesion, as in the case of sand, but chemically by subjecting the organic matters in the water to a process of oxidation, by which, if the filtration is complete, the decaying organic matter is burnt out of the water and destroyed. But even such filters are not invariably to be depended upon, and in corroboration of Dr. Voelcker's view we may mention that Dr. Holdsworth, who gave evidence in support of the Wakefield Water Bill, 1874, stated that he has frequently discovered by microscopic examination living organisms in the water taken from the tap in his house in Wakefield,[1] and the water

[1] Wakefield Water Bill, 1874; Evidence of Dr. Holdsworth; House of Lords, p. 80, Question 1226, *et seq.* In one case Dr. Frankland pointed out that the fine granular matters upon which diarrhœal diseases depend for their origin, pass through every filter which has been tried to arrest them. Wakefield Water Bill, 1874; Lords, Evidence, p. 177, Question 2785. In another case Dr. Frankland remarked, "I

supplied to the consumers had been passed not merely through mechanical filters, but through Spenser's filter of magnetic carbonide of iron, which cost the Company £20,000; and Dr. Letheby in the same inquiry said that "minute organisms may be found in water after filtration."[1] And in reference to these minute organisms we may quote the words of Dr. Hassall, who says—"All living matter contained in water used for drink, since it is in no way necessary to it, and is not present in the purest water, is to be regarded as contamination and impurity, is therefore more or less injurious, and is consequently to be avoided. There is," he adds, "yet another view to be taken of the presence of these creatures in water, viz. that when not injurious themselves, they are yet to be regarded as tests of the impurity of the water in which they are found."

There seems then to be good reason to doubt the efficacy of all artificial filtration, and to have recourse, when it is practicable, to water which has been filtered naturally, or, in other words, to springs or deep wells.

A great many towns depend for their supply upon springs. Cheltenham, as we know, from what has

do not think it is possible by any practicable means that have been suggested to purify sewage so as to guarantee its freedom from the elements of disease."—Cheltenham Water Bill, 1878; Evidence, p. 168, Question 2882.

[1] Wakefield Water Bill, 1874; House of Lords, p. 180, Question 2821. Dr. Cayley seems to think that irrigation and any ordinary filtration is useless in so far as separating or rendering inert the specific poison of typhoid fever is concerned.—Croonian Lecture, 13th March, 1880. *Brit. Med. Journ.* p. 392.

already been said, derives its supply from springs in the Cotswolds. Edinburgh derives its supply from springs in the Pentlands, and Lancaster also draws its water from a like source, and so does Bath. Deep well waters in the chalk and red sandstone are also largely resorted to, and until recently, when Dr. Thorne Thorne's report to the Local Government Board upon the epidemic of enteric fever at Redhill and Caterham showed the possibility of dangers from such supplies which had scarcely been anticipated, were thought the safest of all sources. Nottingham draws its supply from deep wells sunk in the red sandstone. Birmingham gets much of its water, and Liverpool gets some of its water, from wells sunk in the same strata. The Kent Water Company, which supplies a district in London, and concerning the water of which the Rivers Pollution Commissioners say in their Sixth Report:—"The supply of such water to the metropolis generally would be a priceless boon, and would at once confer upon it an absolute immunity from epidemics of cholera"—has its wells in the chalk, like the Caterham Company, which supplies Caterham and Redhill, and an important district in the vicinity of those places. The objection which is most frequently urged against deep-well waters is that they are usually hard, and it cannot be doubted that that is to a large extent true. The important question, however, to be determined in this connection is, whether it is more important to have a water free from organic impurities, or without the saline qualities which make it less desirable as a means of manufacture. The sanitarian would have little difficulty in answering the question. We will deal with the relative merits of hard and soft water hereafter. In this place, however, we may say, that many competent authorities believe that a moderately hard water is best for dietetic purposes.[1] The existence of considerable quantities of saline matter in deep-well waters, has often been used as an objection against a supply from such a source.[2] In many cases the saline matter consists of carbonate of soda and chloride of sodium; but the existence of these substances in the water in considerable quantities, does not take from its excellence. Thus Dr. Frankland mentions the Trafalgar Square water (a deep well water), which is specially supplied to Buckingham Palace for the use of the Queen and her household, to the Houses of Parliament, and to one or two clubs—as one of the best waters he is acquainted with.[3] Yet it contains 16·55 parts of chlorine in 100,000 parts. But many wholesome supplies contain much larger proportions. Thus the well supplying Braintree in Essex which gives a water quite suitable for domestic supply, contains 38·8 parts of chlorine. The water which is supplied to Harrow-on-the-Hill is a most excellent water, and contains 16·5. The

[1] Durham Water Bill, 1878; Evidence of Mr. Hawkesley, C.E. p 53, Question 876.

[2] Dyspepsia is said to be caused by water containing more than 8 grains per gallon of sulphate of lime, chloride of calcium, and the magnesian salts.

[3] Wakefield Water Bill, 1876; Evidence, p. 68, Question 985.

Royal Mint well—a deep well in the chalk below the London clay—contains 13·9; the well at Barclay's Brewery 14; the well at the Albert Hall 15·1; the well at the Midland Railway Station at St. Pancras 11·12; and the well at the waterworks at Witham in Essex contains 12·2.[1] It is to be remembered that chloride of sodium is common salt, that carbonate of soda is used in most London teapots, and that after all 38 parts in 100,000, is no very great thing.

In the inquiry as to the propriety of the Wakefield Water Company taking its water from a deep well in the Oaks Rock—a grey porous sandstone, one of the upper coal measures[2] at the Wath Main Colliery in the valley of the Dearn—it was suggested, as it contained not only salts of lime, but salts of magnesia, it would be a deleterious water for a town supply. The quantity of magnesia present in the water was very small, being from 3·23 to 3·37 in 100,000 parts, and it was pointed out that in the unexceptionable water which was at the time being supplied to Sunderland the quantity of magnesia was somewhat greater, being in fact 4 parts in 100,000.[3]

It is not unfrequently the case that deep-well waters have a faint smell of sulphuretted hydrogen when they are first raised from the sinking, which is in part due to a very minute trace of that gas in the water. It is

[1] Wakefield Water Bill, 1876; Evidence of Dr. Frankland, p. 69, Question 990.

[2] *Ibid.* See Evidence of Professor Anstead, p. 134, *et seq.*

[3] *Ibid.* See analysis by Professor Way and Mr. Ogston, Appendix, p. 98; and evidence of Dr. Frankland, p. 68, Question 989.

found, however, usually in a much more intense degree in the Harrogate water, and in the water supplied to Folkestone, which is drawn from the green sand, and is a very pure water. It is discoverable in these instances when the water is first exposed to the air, but it disappears almost immediately, so that long before the water has reached the consumer all trace of the sulphuretted hydrogen has passed away. The water drawn from the Oaks Rock at Wath, has most of the bad qualities which we have been enumerating, but Dr. Odling thought it a water of exceedingly good quality, both as regards health and general fitness for supply.[1] Professor Way thought it very good for domestic purposes.[2] Dr. Ogston said it was an exceptionally good water.[3] Dr. Tidy reported that it was "a most excellent water, and admirably suited for a town supply,"[4] and Dr. Frankland "knew of scarcely any water in the kingdom he would prefer to it for constant use."[5] It is only fair to add, however, that a good many chemists were called on the other side—Dr. Redwood, Mr. Wanklyn, and Mr. Dugald Campbell, and that Mr. Wanklyn expressed his opinion that it was a bad water, both for drinking and for manufacturing purposes;[6] and again he said, "I object to the

[1] Wakefield Water Bill, 1876; Evidence, p. 10, Question 139.

[2] *Ibid.* Evidence, p. 81, Question 1131.

[3] *Ibid.* Evidence, p. 103, Question 1403.

[4] *Ibid.* Evidence, p. 98, Question 1381.

[5] *Ibid* Evidence, p. 96, Question 996. Dr. Frankland's analysis of this water will be found in the Appendix, p. 99.

[6] *Ibid.* P. 232, Question 4129.

water most strongly; the water is not a drinking, but a mineral water."[1] The Committee of the House of Commons, however, agreed with the first-mentioned chemists, and passed the Bill, authorising the Wakefield Water Company to take water from that source for the supply of the town. As we pointed out above, Wakefield was very unwilling to take a hard water, and very soon after the Bill of 1876 became law, the undertaking of the Company passed into the hands of the Corporation, by agreement, for the sum of £208,000. But the Oaks Rock at the Wath Main is still to be resorted to as a source of supply for an important district of country, a new company, called the Dearn Valley Water Company, having been formed to carry out the undertaking which the Corporation of Wakefield abandoned. The Bill for that purpose was introduced into Parliament during the first session of 1880, and has passed unopposed through one of the Houses.

Before leaving the subject of supply from deep wells, it seems necessary to refer to Dr. Thorne Thorne's very able report to the Local Government Board on the epidemic of enteric fever at Redhill and Caterham.[2] The epidemic seems to have commenced on January 19, 1879, and to have spread very rapidly over the rural sanitary districts of Reigate and Godstone. The number of persons who suffered from the disease was, as far as can be ascertained by most painstaking inquiries, 352.

[1] Wakefield Water Bill, 1876; P. 233, Question 4142.

[2] For a copy of this very valuable document I am indebted to the very careful and capable reporter.

Dr. Thorne Thorne, after a very thorough investigation as to the system of drainage in connection with the residences of the persons affected, as to the possibility of the communication of the infection by means of the milk supply—as in the case of the Marylebone epidemic examined and described by the late Dr. Murchison,—came to the conclusion that the water supplied by the Caterham Waterworks Company had been the means of propagating the disease. It was no doubt difficult, at first, to believe that water drawn from a very deep well in the chalk—which is an admirable filtering and cleansing material for water [1]—water which was deservedly held in very high repute in the district,[2] could be the means of spreading this disease.[3] But Dr. Thorne Thorne's investigations were most careful, and his conclusions are convincing. The Caterham Waterworks Company were at the end of 1878 and the beginning of 1879, sinking a new well about 90 feet from the two then existing wells, and the adit from the old well to the new bore, was at a depth of 455 feet. Men were employed in making this adit, and one of them had, it seems certain, suffered from enteric fever during a portion of the time that he had been employed as "loading man" at the foot of the well; had suffered from constant diarrhœa, and had been compelled, notwithstanding the preparations he had made before descend-

[1] See *Sixth Report of the Rivers' Pollution Commissioners.*

[2] Dr. Thorne Thorne's *Report*, p. 3.

[3] "The freedom from such diseases as enteric fever and diarrhœa, which had been remarked by competent observers in the district, had been attributed to the wholesome water supply."—*Report*, p. 3.

ing, to relieve his bowels two or three times during each "shift," but always, according to his statement, making use of one of the buckets which carried the excavated chalk to the surface. But although the man himself seems to have used due precautions, and the regulations of the Company were prudent and careful, it is evident that there is a strong probability that his evacuations had means of getting into the water. The character of the stools was very watery. The buckets, when drawn up, struck against the sides of the shaft, and the contents were sometimes shaken out and fell over a stage into the workings. It seems certain, then, that the epidemic at Caterham and Redhill was caused by the supply through the Water Company's pipes, of the water infected by the minute quantities of excrementitious matter, passing into the water from this man. Not only does the fact that of ninety-six houses affected in the first fortnight of the epidemic, ninety-one were habitually supplied with water by the Company, show this, but the equally significant fact mentioned by Dr. Thorne Thorne, that the village of Warlingham, which also drew its water from the Company's mains, practically escaped the epidemic, the water for the supply of that village, during the time that the Caterham Well water was infected, having been drawn from a supplementary supply at Kinley, points strongly and clearly to the same conclusion. It was necessary to refer to this case, for it suggests the possibility of dangers which seem scarcely to have been contemplated by the advocates of the deep-well system, and the necessity of greater precautions than seem to be taken in relation to such sources. But although Dr. Cayley, in his Croonian Lectures of this year,[1] seems to think that the result of Dr. Thorne Thorne's investigations may be the foundation of a condemnation of deep-well waters, and of a commendation of river waters, even where these are liable to sewage contamination, we cannot agree with him, we are not sure that he at all times agrees with himself in this conclusion, and we shall have an opportunity of giving the reasons why we dissent from that opinion. Here we would say that regular medical inspection of the workers in wells, which are actually supplying, or shortly about to supply, water to consumers, ought in all cases to be insisted upon. Had that precaution been taken at Caterham, we cannot but believe that the illness of J. K. would have been at once discovered by the vigilance of such a medical officer as Mr. Jacob (who assisted Dr. Thorne Thorne in his investigation), and an epidemic which is known to have affected 352 persons, and to have ended fatally in 21 cases, would have been prevented.

MEANS OF SUPPLY.

We have already had occasion to refer incidentally to the two kinds of works which are used for water-supply. These are, broadly speaking, gravitation and

[1] Published in the *British Medical Journal*, 13th and 20th March, 1880.

pumping works; but the two are often combined in a system of supply. There is no good word to be said for a shallow-well system in a town. Even in country places it is wise to be suspicious of shallow wells. In many cases these are fed by percolation from neighbouring cesspools, and even where they have been so placed that the refuse of the cesspool, the house, and the farm-yard does not flow directly into them, they not unfrequently receive the surface-waters of fields which have been highly manured, and they may be accessible to various other means of injury to health and actual contagion. In populous places, of course, no shallow well ought to be trusted, and in most towns they are gradually being closed by order of the sanitary authorities.

Gravitation works have already been sufficiently described. The water in such cases is impounded in some hill valley, by means either of an embankment of earth with a puddle wall in it, or by an embankment of masonry, at such an elevation above the town or district to be supplied, that the water will reach the tops of the highest houses by natural gravitation. That is not only an important matter in relation to domestic supply, but is all important with a view to the extinguishing of fires. The Manchester Longdendale Works are an excellent example of artificial gravitation works. Loch Katrine is a natural reservoir, and Thirlmere, when the level of the lake is raised fifty feet by Mr. Bateman's embankment, will be a hybrid between a natural and an artificial reservoir. Thirlmere is 533 feet above ordnance datum. In most gravitation works the water is conveyed in a cast-iron pipe, which follows the inequalities of the surface of the land, and passes over the valleys in inverted siphons. The Glasgow supply from Loch Katrine is carried four miles in iron pipes across valleys, and the Thirlmere to Manchester will be carried more than five of its hundred miles' course, by similar means. The reservoirs for the supply of a town by gravitation, ought to be of such a size that they will contain a sufficient quantity of water for the supply during the longest possible drought. It is by the dry weather happening in such years as 1826 and 1868, that the capacity of our reservoirs must be tested. It is therefore usual to make them of sufficient capacity to contain certainly not less than five or six months' supply, for the population and trade they are to serve. The amount of water which must be stored for that purpose, can only be determined in relation to the amount which will be consumed per head of the population, a subject concerning which we shall have more to say hereafter; but here we may remark that the allowance in Glasgow seems to be about fifty gallons a head per day, while in Norwich it is about fifteen; and the latter figure includes the inevitable waste and the supply for trades.[1]

As to the distribution of water over the supply district, we need say little. There are two methods by which the water is distributed. It is either a constant or an intermittent supply. In case the

[1] Stockton and Middlesborough Arbitration, January, 1878; Evidence of Mr. Ayris, C.E., p. 434, Question 4454.

supply is constant, no cistern is necessary, for the supply pipes are constantly charged, and usually at high pressure,—which renders it necessary to have strong house fittings,—with water from the service reservoir or nearest break tank. But in case the supply is intermittent, a tank or cistern is necessary in connection with the service-pipe of each house supplied. The water is turned on once a day for a sufficient time to fill these cisterns, but in case the cisterns have not been drawn down the preceding day, the supply pipe is closed by a ball-cock, so that unless the ball-cock is out of order, there is no waste of water from the supply to households of more water than they require. Very few companies or corporations seeking Parliamentary powers in these days, ask to be allowed to adopt the intermittent system, which is in every way less advantageous to the consumer than a constant supply, and is not found to be so economical of water to the Company as a constant pressure system, guarded by sufficient rules and regulations against waste. One obvious disadvantage of the intermittent system, which is still, unfortunately, the system of supply in London, is that the water is not always ready in the mains and available in cases of fire. The turncock has to be found, and the mains charged, at the very time when the water would, if it had been available, have been of the most use. But there is another important consideration which is not unfrequently lost sight of. There is not only expense connected with the construction and repair of cisterns, there is not only likely to be great carelessness in the keeping of them clean when they are in use, for they are mostly in places it is difficult to get at, but they are very apt to be contaminated by neighbouring sources of pollution. Dr. Cayley says that he believes that in the case of two-thirds of the cisterns in London houses, the waste pipe from the supply cistern goes directly into the soil pipe, so that the drinking water is "habitually contaminated with sewer gas."[1] Sewer gas has innumerable ways made for it into a house. Thus in most houses the sinks are untrapped. In almost every house the displaced water from the water-closet forces up the air from the drains. The overflow-pipe from a balcony opening in front of a drawing-room window goes directly into the main sewer, and so on. We are convinced too that in a larger number of instances, not only are the cisterns uncovered, so that they become the invariable receptacle for dust, the aquaria for various forms of life, and the causes of disease; but that they are very seldom or never cleaned. Most cisterns, too, are made of lead, a material which is apt to be acted upon by most soft waters—but not always in proportion to their softness—in such a way that the water when drunk may affect the consumer with all the symptoms of lead poisoning. The waters which are most likely to be contaminated by lead, are very soft lake and river waters. Distilled water has a very intense action upon

[1] Croonian Lectures for 1880, in *British Medical Journal*, 20th March, 1880, p. 433. See also Dr. Pridgeon Teal's *Dangers to Health in Houses*.

lead. The water of Loch Katrine, too, is known to be intensely affected by lead. Two conditions seem to be necessary to the very intense action we have referred to, viz., that the lead should be bright and polished, and that air should have free access to the lead and the water. It seems, too, that the presence of vegetable matter in the water may heighten the effect. The circumstance that dull lead is not so easily acted upon as bright lead, has always been an excuse, if it has not been a reason for, dirty cisterns. The possibility of poisoning by lead by means of water which has been allowed to remain for some time in contact with lead either in cisterns or in long pipes, was largely dwelt upon, both by Dr. Frankland and Dr. Tidy, in their evidence in the Thirsk Water Provisional Order Bill, 1879, and most chemists now test soft waters to see whether they have much or little action upon lead.[1] Cisterns ought to be made of slate, and covered. A less expensive lining for a cistern has been found in gutta percha, which is said to be easily fitted and durable. The objection to lead cisterns, which we have been referring to, is sometimes extended to the use of lead pipes, whether employed as distributing mains or distributing service pipes. But the only danger in such a case is where water has been allowed to rest in long pipes for a very long time; and where the water which has been lying in the pipes is run off and not used, little harm is likely to be done. A royal family is said to have

[1] Wakefield Corporation Water Bill, 1880; Evidence of Mr. Dugald Campbell.

been poisoned in this way, but the case seems to be but vaguely authenticated. Dr. Frankland, while he was resident in Manchester, had a servant who suffered from lead poisoning; but whether the water which conveyed the lead was contaminated by the cistern or the pipes, we do not remember. Although Drs. Christison, Taylor, Miller, and Guy have dealt with this subject, the cases in which actual mischief has been done by these means, seem to be very few. Galvanised iron pipes, which are as cheap as lead, can be used instead of them, and the risk of lead poisoning in this way avoided. The question of cisterns, which we have dwelt upon at some length, was introduced by a consideration of the intermittent system of supply, which renders the use of cisterns or house-tanks necessary.

We have said enough of gravitation works and the means of supply from them; it remains to say something of pumping works. There are, of course, two kinds of pumping works, in the one the water is pumped from rivers, as it is in London, and as it used to be in a great number of other places; and in the other it is pumped from deep wells, as it is by the Kent Water Company, and by many other companies and corporations. In both these descriptions of pumping works, power is necessary to lift and propel the water to the necessary height. As we have seen, the power, in most cases steam, may be used merely to elevate the water to a service reservoir at a high level, from which it can be distributed by gravitation, or it may be used for the purpose of pumping over stand-pipes, so as to force the water into the consumers' cisterns. When river water is pumped by those means it is usual to allow the water so raised to pass into subsiding ponds, in order that the matter which it holds in suspension, which is usually in considerable quantity after floods, may be discharged from it by subsidence before it is turned on to the filter beds. In very few cases can river water be fitted for supply without filtration, and in most cases where the sources of rivers are collected from large catchment areas the waters are subjected to mechanical filtration before delivery. The effect of subsidence upon turbid water is seen upon a large scale in rivers which flow through lakes. It is well known that the Rhone enters the Lake of Geneva at the upper end yellow and turbid, and leaves at the lower end as clear as glass. But the same phenomena can be seen in any of our Cumberland or Highland lakes, which are fed by brown and amber floods, and which send out pure streams. In all subsiding ponds, as in the natural subsiding ponds we have been referring to, the water is run off the top, and in these ponds in waterworks, arrangements are made by which the mud and discharged matter collects at one part of the basin, and can, when the whole water is run off, be removed from time to time. Waters of different qualities are said to clear themselves more rapidly by subsidence when mixed, than when separate.

It is well too, that pumping works should not only have a subsiding reservoir, but that they should be provided with a few days' storage at least, in order that they may be able to refrain from pumping from the river when it is at its worst. London Companies provide subsiding reservoirs equal to at least six days' supply,[1] and it is necessary that the area of the filter beds should be in proportion to the amount of the water which has to be passed through them. Thus, before the Committee on the Stockton and Middlesborough Water Bill, 1875, it appeared from the evidence of Mr. Hawksley, that in the case of the Tees, six inches in the hour was a proper rate of filtration, or a depth of twelve feet in the twenty-four hours.[2] And we may say that as a rule a clean filter ought to pass about that amount of water in that time. Mr. J. F. Bateman said, "A well-constructed filter will filter ordinary water such as would be taken from a river in good condition, or from a reservoir after subsidence, at the rate of about six inches in the hour, that is, seventy-five gallons for every square foot of filter in twenty-four hours."[3] But taking the area of the filter-bed and the amount of water passed through it, it appeared that the rate of filtration must be 50 per cent. quicker than that, or at the rate of nine inches in the hour in depth,[4] and therefore a great deal too fast, so that the water was often delivered in a half-filtered state.[5]

[1] Stockton and Middlesborough Water Bill, 1875; Evidence of Mr. Mansergh, C.E. p. 380, Question 5629.

[2] Evidence, p. 149, Questions 2277-2279.

[3] Stockton and Middlesborough Water Bill, 1875, p. 402, Ques. 5886.

[4] Stockton and Middlesborough Water Bill, 1875; Evidence of Mr. Mansergh, p. 379, Question 5625.

[5] Stockton and Middlesborough Corporations' Water Bill, 1876;

The water when passed through the filter is supplied to the consumers in the way we have already described. But in speaking of the size of impounding reservoirs for gravitation schemes, and of the size of subsiding ponds and filter beds for pumping schemes, we have seen that their dimensions are only to be determined relatively to the day's supply; so it comes to be a matter of importance to determine what is the proper supply per head per day, and if that can be accurately ascertained the mere multiplication of that figure by the number of the population to be supplied, will give you a basis for your calculations. But no absolute figure applicable to all places can be found; indeed the amount of water to be allowed per head for a town's supply, varies very greatly in relation to a great number of conditions. We have seen that at Glasgow the consumption is somewhere about fifty gallons a head per day, which is to some extent accounted for by the fact that water-closets are more numerous in that city in proportion to the population than in most other towns,—while in Norwich it is only fifteen. In London it is about twenty-six gallons a head, while in Edinburgh it is thirty-four. In each case the proper amount to be supplied per head, can only be determined after a consideration of all the circumstances.

The most important circumstance to be taken into consideration in such a case, is the existence or non-existence of water-using trades. In Stockton and

Evidence of Mr. Mansergh, p. 193 (27th March, 1876), Questions 32 and 35.

Middlesborough, about one-half of the whole water drawn from the river was consumed by the iron trades. In Norwich only three gallons a head per day is used for trade purposes, and in Sheffield only four; while in many places there are no trades which would make any appreciable difference in the consumption, and in some the manufacturers have other means of supply. The existence or non-existence of water-closets in a town makes a material difference in the amount consumed. Then the possibility not only of the careless use of water in the houses of the consumers, but of preventible waste underground, must be contemplated, and can now happily be guarded against by the use of Mr. Deacon's metre. The consumption, too, varies at different periods of the year, rising in summer, and in different years as they happen to be wet or dry, for upon these circumstances depends the amount of water which is taken for watering streets and gardens, and the like. Mr. Ayris, C.E., a very great authority upon all questions of consumption, thinks that the summer consumption in a town like Sheffield might be 10 per cent. above the average for the year;[1] and it was proved before the Select Committee on the Manchester Corporation Water (Thirlmere) Bill, 1878, that the normal rate of increase in consumption in Manchester, which had for some years been such as to make about 1,000,000 gallons a day more necessary each successive

[1] Stockton and Middlesborough Arbitration, Jan. 1878, p. 46 Question 4830.

year, had not been maintained during the preceding year, partly owing to the wetness of the weather, and partly, no doubt, to the depression of trade. All these facts show that there may be some difficulty in arriving at the correct amount to be allowed in any particular case, and may account for a good many apparently conflicting views as to what is sufficient.[1] First, the fact seems to be that the actual consumption for domestic use and inevitable waste at Nottingham is fourteen gallons a head per day, and Mr. Ayris is of opinion that that amount could, by means of regulations and rules, which would, he admits, be troublesome and inconvenient to the inhabitants, be reduced to eight or nine gallons a head per day.[2] The actual consumption at Norwich is, as we have said, fifteen gallons a head, and that includes the trade, which, as Mr. Ayris showed, uses at the rate of three gallons a head per day.[3] At Sheffield the consumption used to be forty

[1] An adult man, of about ten stone weight, will use, for food purposes, from seventy to ninety ounces of water in the twenty-four hours, a good deal more than half that amount being taken in a liquid form, while the remainder is taken in solid food. Dr. Parkes thinks that four gallons per head daily is the smallest amount which ought to be allowed to secure personal cleanliness, and if baths are taken that amount will be quite inadequate. A shower-bath may require about six gallons, a hip-bath about twelve gallons, and a plunge-bath about fifty gallons. Water-closets, where they are employed for the disposal of sewage, and occasional flushing of the drains, may require about eight or nine gallons per head per day. As to the consequences of an insufficient supply of water, see Report of the Health of Towns Commissioner, 1844 and 1845.

[2] Stockton and Middlesborough Arbitration, Jan. 1878; Evidence of Mr. Ayris, p. 433.

[3] *Ibid* p. 434, Question 4454.

gallons a head per day, but by the introduction of regulations for checking waste, the consumption has been reduced to eighteen gallons.[1] It is fair to say, that part of this reduction was effected by improvement in house-fittings and in the pipes communicating with the Company's mains. The present consumption of Manchester, including trade, is twenty-five gallons a head, and the calculations as to the consumption in the future were, by the Select Committee which inquired into the Thirlmere scheme in 1878, taken upon the basis of that figure.[2] In Liverpool the consumption for domestic purposes is fifteen gallons a head.[3] The opinions of experts vary considerably as to the quantity to be allowed. Mr. Bramwell, C.E., says that fifteen gallons a head to cover domestic supply, small traders, or unpreventable waste, is ample.[4] Mr. Ayris seems to think fourteen gallons a head ample. Mr. Hawkesley says: "In a well-managed waterworks where there is no waste, the gallons per head are about nineteen."[5] Thus both Mr. Bateman and Mr. Hawkesley think that twenty gallons a head per day, is amply

[1] Stockton and Middlesborough Arbitration, Jan. 1878; Evidence of Mr. Ayris, p. 466, Question 4461.

[2] See *Report of Select Committee on Manchester Corporation Water Bill*, 1878.

[3] Cheltenham Water Bill, 1878; Evidence of Mr. Hawkesley p. 94, Question 1238.

[4] Stockton and Middlesborough Arbitration, 1878, p. 613, Question 5942.

[5] Wakefield Water Bill, 1874; Commons, Evidence, p. 73, Question 1110.

sufficient for such a town as Cheltenham.[1] In the Stockton and Middlesborough Bill, 1875, Mr. Hawkesley was asked, "What do you calculate the summer supply per head?" And he answered, "Twenty-five gallons per head in summer is a very moderate calculation. That includes all the trades except the trades of iron manufactures; it includes sanitary purposes."[2] But when he had another opportunity of explaining his view in the following year he said, "The domestic supply at Stockton and Middlesborough is about twenty-five or twenty-six gallons a head per diem; that is a great deal; it is just double the quantity which is actually used in all the great towns of the kingdom, where proper rules and regulations with regard to the fittings are in use."[3]

There can be no doubt that the regulations as to fittings, and the careful means now employed for the detection of waste, have a great deal to do with the restriction of the consumption. The limitation of the consumption at Sheffield is an indication of the efficiency of these means. Another instance is afforded by Liverpool, where the consumption in 1871 was 28·67 gallons per head per day, with only a twelve hours' service, while in 1878 the consumption, less manufacture, was at the metre 16·57 gallons per head per day,

[1] Cheltenham Water Bill, 1878; Evidence of Mr. Bateman, p. 212, Question 3578; Mr. Hawkesley, p. 93, Question 1237.

[2] Stockton and Middlesborough Water Bill, 1875; Evidence, p. 106, Question 1762.

[3] Stockton and Middlesborough Water Bill, 1876, p. 280, Ques. 3991.

and the service in the latter year was constant.[1] One of the means employed in Liverpool for the detection of leakage is, as we have said, Mr. Deacon's metre. The means by which this is effected are very simple. The metre is attached to a pipe through which the supply to a certain number of houses is conveyed at a time when the consumption ought to be least, as at midnight, and the then flow of water determined. If the amount seems excessive an inspection of the inlet cocks, which are connected with the service-pipes of each house, is made. By using the spanner which turns the inlet-cock as a stethoscope, you can tell whether the water is running through that cock or not. By shutting off the houses into which water was running, as thus ascertained, and by again measuring the flow at the metre, you can come to a conclusion as to where the real waste of water occurs, and whether the house consumption accounts for the whole flow, or whether there is a leakage in the pipes between the metre and the inlet-cocks. When the occasion of the waste has been discovered and localised, it is easy to remedy the defect. By the adoption of these and other means, such as screw-down taps and the like, what is called consumption, but what is, in fact, preventable waste, is to a large extent restricted.

[1] Stockton and Middlesborough Arbitration, 1878; Evidence of Mr. Bramwell, p. 614, Question 5946.

THE QUALITY OF WATER.

We have now to speak of the quality of water used for towns' supply. One thing, which need not detain us long, is the mineral matter which many waters hold in suspension. These waters, if allowed to rest in subsiding reservoirs, for the most part free themselves from the fine mineral matter which they carry, and if, even after a sufficient time has been allowed to them, they still have some matter in them when they leave the subsiding pond, it will in most cases be removed by filtration. These remarks are not quite true of the particles of clay which seem to be suspended in water by some adhesion between them and the liquid which envelops them, and the particles are so fine that they pass with impunity through the meshes of the finest filter. But mineral matter in water is a matter of comparative unimportance.[1] A much more important question arises in connection with mineral matters in solution. As we have seen, spring, and deep-well, and most river waters, contain considerable amounts of dissolved mineral matters. Spring and deep-well waters are generally free from all organic impurities; but the natural filtration through various strata, while it takes from the waters all organic impurity, gives to them chemical qualities which are not met with in rain or surface water. Any water

[1] It is said that diarrhœa is caused by the use of waters in which much clay is held in suspension, which is the case in the waters of the Ganges and of some of the North American rivers.

which is for any length of time in contact with soluble mineral matter, takes up some portion of the matter into itself; and consequently in river water, and waters which have percolated through rocks, we find traces of mineral ingredients.[1] The mineral matter which is usually held in solution in these waters, consists of salts of lime, magnesia, soda, and potash. Lime and magnesia are the salts which cause waters to become hard. The salt of lime, which is most frequently found in spring waters, is the bicarbonate. Chalk or limestone, from which many of our excellent waters are drawn, is a carbonate of lime, or, in other words, a compound of lime with one equivalent of carbonic acid. But a carbonate of lime is not soluble in water, and unless the water brings with it a contribution of carbonic acid, which is very often the case with spring waters, and converts the carbonate into a bicarbonate, which is soluble in water, there would be no mineral matter in solution in the case of waters flowing through chalk. When, however, the water brings sufficient carbonic acid to change

[1] Good drinking water must, according to the late Dr. Parkes, in his *Manual of Practical Hygiene*, "be transparent, colourless, without odour, and tasteless; it should be aërated (as it thus appears to be more easily absorbed), cool, and pleasant to drink; it must have no deposit; vegetables should be readily cooked in it; the total dissolved constituents must be within a certain amount, which, with some limitations, may be represented by the following numbers: organic matter should not exceed 1·5 grain per gallon; carbonate of lime, 16 grains; sulphate of lime, 3 grains; carbonate and sulphate of magnesia, 3 grains; chloride of sodium, 10 grains; carbonate of soda, 20 grains; sulphate of soda, 6 grains; and iron, 0·5 of a grain."

the carbonate into a bicarbonate, then the bicarbonate passes in solution into the water. Sulphate of lime is also often found in water. The bicarbonate can, to some extent, be precipitated by boiling, the sulphate cannot.

Of course magnesia is a valuable medicine when taken in large doses, and might be present in water in such quantities as to unfit it for a town supply, and make it a medicinal water. Even in the small quantities in which it is found in some of our deep-well waters, it may not be without some effect upon the human organism.[1] The salts of soda and potash found in water, do not affect the hardness of the water, and the principal salt of those substances which have to be dealt with in the water analysis, is chloride of sodium—or common salt. Sulphate of sodium (Glauber salts) is sometimes found. We are here dealing only with the question of water as fitted for town supply, and have nothing to do with the question of the medicinal waters which are given out by so-called mineral springs. No one could of course recommend such waters for town supplies, although a suggestion was made in one case last year, that the town of Thirsk should collect certain very hard spring waters, one of which was a petrifying spring—with, we think, 56° of hardness—instead of impounding some very soft (with 3·6° of hardness) and excellent hill-water above Boltby.[2] But when these salts, or some of them, are present

[1] See note, *ante*, p. 33.

[2] See Thirsk Water (Provisional Order) Bill, 1879; Evidence of Mr. Fairlie; Commons, p. 33, Question 577.

in small quantities, when the hardness is not materially affected, and is not above 16°, it seems that the water may be an excellent, palatable, and, as the American called it, a "sprightly water," very well suited for potable purposes, and not ill-adapted for certain kinds of manufactures. They do not by their presence in small quantities take the waters out of the category of ordinary potable waters, as the salts of iron would, which would make the waters chalybeate, or medicinal waters; and we have thought it best, with the view of showing in what quantities these may exist in water which was pronounced an excellent water for supply by Drs. Frankland, Odling, Tidy, and Ogston, and Professor Way, to give two analyses of the Wath Water in the Appendix to this work. These are the analysis of Dr. Frankland, and the joint analysis of Professor Way and Dr. Ogston, and will be found in the Appendix, pp. 98, 99. It is only fair to say that this is the water of which Mr. Wanklyn said, differing diametrically from all the authorities we have mentioned, that it was "a bad water both for drinking and manufacturing purposes."[1] The Committee of the House of Commons, however, agreed with the views of the former.

The salts of magnesia and lime are principally objected to when present, because of the effect they have upon the hardness of the water, and this leads us to the much disputed question as to whether a hard or a soft water is best for the supply of a town, in so far

[1] Wakefield Water Bill, 1876, p. 232, Question 4129.

as dietetic purposes are concerned. We have already pointed out that for almost all manufacturing purposes, but especially for those in which soap is largely employed, soft water is preferable to hard; and we know of no trade that is better carried on by means of hard water than by means of soft, except the brewing of pale ale. Where water is used for steam purposes, the "fur" which is deposited from hard waters upon boilers, is often a very serious disadvantage. The disadvantage which arises from the presence of the salts which cause hardness in water, in so far as manufacturing interests are concerned, may be gathered from the fact that every grain of chalk which is contained in water, decomposes ten grains of soap. Faraday used to define a fool as "a man who had never made an experiment." But every one in washing his hands has experimented upon the hardness and softness of water—it may have been forty years without knowing it, like M. Jourdain in Molière's play—by the ease or difficulty with which he secured a lather. The waste of soap occasioned by hard water is of course very considerable, and besides the waste of soap, there is much more tear and wear to the things that have to be cleansed with the hard water, not to speak of the additional labour which such waters necessitate. Hardness is measured by degrees. One grain of chalk in a gallon is the measure of one degree, two grains per gallon of two degrees of hardness, and so on. But the question of the advantages or disadvantages of hard water for manufacturing purposes, such as scouring, dyeing, and steam purposes, is a very different question from that which has been so often proposed and so variously answered. Is soft water better for drinking purposes than hard? Mr. Hawkesley, who is one of the highest authorities on all questions of water supply, says "a moderately hard water is best for dietetic purposes,"[1] and a moderately hard water is, according to Drs. Letheby and Tidy, one of from 10° to 11° degrees. Mr. Bateman, who has, we think, been a consistent advocate of soft water, although certainly no bigot in its favour, in giving evidence before the Duke of Richmond's Commission on Water Supply, thus refers to the evidence which had been given before the Commissioners. "You have had twenty-seven (witnesses) who have all expressed an opinion in favour of soft water, some of them very strongly in favour indeed. You have one single gentleman who has expressed a decided opinion in favour of hard water, and you have had one gentleman who has expressed a qualified opinion in favour of hard water. Amongst those who have expressed a very strong opinion in favour of soft water are Mr. Rawlinson, Professor Way, Professor Ramsay, Mr. Duncan, Dr. Lyon Playfair—to whose evidence I must specially draw your attention — Mr. Simons, Dr. Farr, who also very specially referred to it, Dr. Parkes, Dr. Frankland, and with him Dr. Odling;" but notwithstanding this evidence and much valuable testimony contributed by

[1] Durham Water Bill, 1878; Evidence, p. 53, Question 876.

Mr. Bateman himself, the Commission did not come to the conclusion that London water, which averages 15°, would be in the least degree prejudicial to health. There is no doubt that soft water saves soap, and is admirably suited to all the industries which our large towns so successfully carry on, and hence it is that Glasgow has sought and procured a water which is only ·8 of a degree of hardness, in Loch Katrine; that Manchester has procured the Longdendale water for its present wants, which is 1·5° of hardness, and Thirlmere for its future requirements, which will afford even a softer water; that Liverpool is promoting a Bill in the present session of Parliament to secure the water of the Vwyrny, which at Pont Hagel is 1·8 degrees of hardness; and that Bradford, Halifax, Bolton, Oldham, Dewsbury, and now Wakefield, have secured abundant soft water supplies. These facts only show that the interests of trade are of paramount importance in these great centres of commerce and manufacture. But on the other side, let us refer to a table which was put in, in the inquiry into the Preamble of the Edinburgh and District Water Bill, 1871. That table showed the quality, as far as hardness was concerned, of the various supplies in sixty-five towns and cities in England and Scotland, and gave the various death-rates in each of these towns. We are unable to speak as to the authority of the table, but we append (see Appendix, p. 101) a summary of the table which seems to show, at least, that in the towns with soft water supplies, the death-rate is not lower than in towns with hard. Of course we are aware that there may be innumerable other circumstances to be taken into consideration in every one of the cases referred to in the table, and that the number referred to may be insufficient to secure a truth from the conflicting errors. But we give the summary for what it is worth.

So far, however, as we have been able to ascertain, altogether apart from that table and summary, it seems certain that from 10° to 15° of hardness is not regarded as a disadvantage in drinking water by most chemists and medical men, and the question whether a soft or a hard water is best for the maintenance of health, must be regarded as quite undecided. There are many advocates, not to say apologists, for London water, which is a hard water. Dr. Frankland, as we have seen,[1] speaks of a great many hard waters as excellent for drinking purposes, and preferred a water of from 15·7° to 16·3° of hardness, upon the 100,000 scale, for the supply of Wakefield, to a soft hill water (1·9°) from the Little Don River, which was proposed as a source of supply in 1874.[2] The water of which Dr. Frankland spoke in this way was that which Mr. Wanklyn condemned in the terms we have quoted above, and also in these words at a subsequent question, "It is an unsuitable water for domestic use, and not a drinking but a mineral water."[3] Dr. Frankland,

[1] *Ante*, p. 33.

[2] Wakefield Water Bill, 1876; Evidence, p. 66, Question 974; and Wakefield Water Bill, 1874; Evidence, p. 56, Question 978.

[3] *Ibid.* Evidence, p. 233, Ques. 4140, 4142.

on the other hand, said the hardness was not objectionable for domestic use,[1] and that he knew of scarcely any water in the kingdom he would prefer for constant use.[2] Under these circumstances we are justified in assuming that the question of hard or soft water, as a sanitary question, cannot be satisfactorily answered one way or other at the present time.

Hard water, as it is well known, can be very much softened by Dr. Clarke's process, a very beautiful adaptation of science to the useful arts. This is not a mere laboratory experiment, but has been applied to the softening of many of the waters drawn from the chalk on a large scale, as for instance at Caterham, Tring, and other places. Chalk water can by this means be reduced from 17° of hardness to from $2\frac{1}{2}$ to $4\frac{1}{2}$ degrees.

We come now to another very important question in relation to the quality of water, and that is the question of organic impurity.[3] We have seen how the waters of springs and rivers become charged with mineral matters, but waters have quite as many opportunities of becoming the carriers of various forms of organic matter, as they have of taking up mineral substances. Not only have they natural opportunities—if we may speak of them in such a way, which are common to all waters which fall upon the earth, upon whose surface plants and animals grow and decay, and

[1] Wakefield Water Bill, 1876, p. 69, Question 1001.

[2] *Ibid.* Evidence, p. 69, Question 996.

[3] As to the effects of impure water upon the sanitary condition of towns, the reports of the late Mr. Simon, at one time Medical Officer of Health to the Privy Council, are most instructive.

plants and animals deposit their refuse—but we have given them artificial opportunities by turning all our sewage into rivers, and by making water the carrier of refuse from our houses to the sea, or at least out of our immediate neighbourhood. Somewhat recently, very strenuous efforts have been made to prevent this abuse of our rivers, and to substitute a more sanitary means of disposing of house refuse than that which we have in water-closets connected with a great drainage system, which empties its filth upon a river. At one time it seemed to be thought that if rivers were not to be trusted, tides were, and outfalls were opened upon ebbing floods. Now, however, the favourite means of disposal of sewage seems to be irrigation. We shall have occasion to speak of this matter hereafter, and to point out that irrigation is not to be relied upon with that confidence as a means to the prevention of any harm from sewage, which some of its advocates seem to have thought. But confidence is always at the service of any new thing.

A complete list of all the possible organic impurities which may be found in water, would be as long as it would be misleading, but we may say shortly, that we find all kinds of decaying vegetable fibres, the putrefying products both of plants and animals; we find starch, urea, and anatomical products, and a great many forms of vegetable and animal life, such as algæ, confervi, fungi, belonging to the former, and infusoriæ, entomostraceæ, annellidæ, &c., belonging to the latter. We know how favourable a stagnant pool is to those forms of life which delight in death and decay; and it is scarcely necessary to say, that the strange brew which ferments in stagnant water, where foul plants afford food for foul animals, is a very unwholesome article of diet. It is this water which we have all looked at under the microscope with shuddering. But luckily we have not to be dependent upon analysis for the rejection of such water, for the palate knows enough to be disgusted at it, without having to call in the aid either of chemical or histological research.[1]

Most of our hill waters fall upon, and flow from, surfaces more or less overgrown with peat and the various plants which grow in such high places, and water filtering through peat mosses is apt not only to be tinged with the colour of peat, but to acquire a somewhat bitter taste. These qualities are not to be desired in a water; they are not, however, found to be consistent with those more disagreeable qualities we have been alluding to, for peat is a strong antiseptic, and does not favour the production of low forms of animal life. In very many cases where towns or cities have asked the sanction of Parliament to the appropriation of hill waters, the objection that the water was

[1] Organic matter, of vegetable origin in water, is of course not nearly so dangerous as that of animal origin, which contains nitrogen. Such matter which gets into water from various sources of pollution, in decomposing produces both nitrous and nitric acid and ammonia, and the nitrites and nitrates thus formed communicate no property to water which can be detected by the palate as distasteful, but rather produce a sparkle in the water which render it acceptable as a beverage. Many of the churchyard waters used to be prized for the very qualities which rendered them most dangerous as potable waters.

peaty has been urged against the scheme. In the inquiry as to the Cleveland Water Bill, 1876, this objection was raised, and it was suggested that the presence of peaty matter in any large quantity might cause diarrhœa, but the Committee, notwithstanding the suggestion, passed the Bill. Mr. George Rowbotham in his pamphlet on "The Supply of Water to London," [1] in which, following Mr. Bateman, he suggested the expediency of going to Central Wales for the supply of London, says,[2] "One strong objection urged to the water from Wales was on account of its colour, it being alleged that it would be 'commonly coloured' from peat. Similar objections were taken, thirty-four years ago, to the then proposed supply of water to Manchester from Longdendale, and samples of water were gravely produced, in colour as brown as coffee, as the kind of water which would be supplied from the new works. It is true that at certain seasons of the year some of the streams which feed the reservoirs of the Manchester Corporation Water-works are, for a time, deeply stained by peat, but the effect of exposure in the large reservoirs is to remove almost entirely all colour; and the water as delivered in Manchester and as seen in a tumbler on a dining-table, is certainly as white and bright as the supplies afforded to the inhabitants of London from the present polluted sources.

"Were no Loch Katrine in existence, and a reservoir had to be made for impounding the waters of the streams which now descend the hills forming the basin

[1] London, July 1879. [2] P. 18.

of the loch, the same strong objections to a supply of water from that district on account of peat stains, would obtain; for in rainy weather, which is the time when gravitation waterworks receive their supplies of water, the two principal streams feeding Loch Katrine flow into it as brown as porter, but the effect of exposure in the large surface of the lake aerates the water, and is such, that when it is taken from the lake for the supply, to Glasgow, a piece of white porcelain, seen at a depth of five feet, is only changed to a very pale straw colour. In cold weather, and in the depth of winter, the water may be said to be absolutely colourless."

We will probably hear more of the suggestion to which Mr. Rowbotham alludes, in the coming inquiry as to the Liverpool Corporation Water Bill, which proposes to take the waters of the Vwyrny, which is in a very peaty district, for the supply of the town. It was suggested by the opposition, on behalf of Darlington, to the Stockton and Middlesborough Corporation Water Bill, 1876, that the diminution of the flood waters by the impounding works proposed under the Bill, would make the water which Darlington draws from the river more peaty, as the peaty water would be less diluted by the storm waters; but this argument, whatever its weight, did not prevail. The question how far the bleaching of water stained by peat takes place in large natural or artificial reservoirs, which is referred to by Mr. Rowbotham, who has had exceptional opportunities of becoming acquainted with the results of storage in the Longdendale reservoirs and

Loch Katrine, seems still to divide scientific opinion. Before the Thirsk Water Company (Provisional Order) Bill, 1879, some witnesses thought that most of the colour was discharged by long exposure, while others thought that the effect of such exposure was very small. It seems certain, however, that water without any taint of peat is more palatable than water which is so "seasoned," but it would be difficult to say that a very slight stain of peat in hill waters renders them unsuitable for a town's supply.

"The chief condition of danger in potable waters is," as the Rivers' Pollution Commissioners remark, "excremental pollution;"[1] and in all questions connected with the selection of a water supply, it is important that waters which are free from any suspicion of poisoning from this source, should be primarily sought for. This, however, does not seem to have been a paramount motive in such investigations. People seem to have thought that a small mixture of pollution from the worst sources would do no harm. For many years the London Companies drew their water from the tideway of the Thames, from a part of the river not only affected by the sewage of Oxford, Reading, and a population of nearly a million people in the Thames valley, but by the refuse and sewage of London itself And when the expediency of compelling the companies to avoid the latter large source of pollution was being discussed, and the expediency of making them draw their water for supply above Teddington lock was

[1] *Third Report*, vol. i. p. 53.

being investigated, there were many who opposed the imposition even of this reasonable restriction upon the companies, and apparently upon the ground that great dilution of poison gave practical immunity from injurious consequences. This theory has been long ago discarded, and the most recent authority upon typhoid fever speaks emphatically in repudiation of such a dangerous doctrine.[1] Let us give another instance of this carelessness to sanitary matters. The town of Wakefield not only took its water from the Calder, the main thoroughfare for the filth of 500,000 people to the sea, but it selected a site for its pumping station three miles below the point at which the town of Wakefield poured its sewage into the river. The carelessness with which companies selected their sources of supply, the little attention which was given to the primary consideration of freedom from pollution by sewage, is somewhat extraordinary. However, as we have seen, the tendency of the times is to have recourse either to the unpolluted head waters of rivers, or to deep-seated springs and wells. We have said that in modern times rivers, instead of being made the means of carrying away sewage, are more commonly made the means of removing merely the effluent waters from lands which have been irrigated by sewage. The schemes for the disposal of sewage by such means are numerous, and the system is much vaunted. Even Mr. Michael seems to think that this will put an end to the evils

[1] See Dr. Cayley's Croonian Lectures, 1880; *British Medical Journal*, 13th and 20th March, 1880.

resulting from most systems for the disposal of sewage, for he says, "By chemical decomposition, by irrigation and filtration, we have sure means of so disposing, and subsequently oxidising, the putrescible matter contained in sewage, that the evil results of its presence may be entirely removed."[1] But we would wish to be very cautious with regard to the use of water which had received the effluent waters of such irrigation works, and in confirmation of this caution, we would refer to the cases quoted by Dr. Cayley in his *Croonian Lectures,* cases from which he draws the following important conclusion. "These instances are," he says, "sufficient of themselves to serve as a warning against trusting to irrigation and downward filtration as a means of purifying water, and also against the dictum that water containing less than a certain proportion of organic impurity is practically wholesome and fit for drinking, irrespective of its original source. It ought," he adds, "I think, to be laid down as a rule of hygiene, that human excrements should under no circumstances be mixed with drinking water, however completely they may be subsequently removed by filtration, or rendered innocuous by oxidation."

But notwithstanding these opinions, it is well to bear in mind that London, although it no longer

[1] *Address on Health.* London, 1879, p. 24. This view is borne out by the resolution of the Leamington Sewage Congress, 1866, which was, "That the system of irrigation, when carried out in a scientific manner, removes the difficulty which now arises from the present noxious plan of polluting the rivers of England." See a very able lecture by Dr. Alfred Carpenter, on "The First Principles of Sanitary Work."—*British Medical Journal,* October 25th, 1879.

drinks the water infected by its own sewage, as it did before 1852, still drinks the water of a river into which a population of over 800,000 pour their sewage, and that neither the Select Committee of the House of Commons of 1867, nor the Royal Commission on Water Supply in 1869, which were appointed to investigate the quality of the water supplied to the metropolis, reported unfavourably of the existing supply. The Select Committee reported that they were "satisfied that both the quantity and quality of the water supplied from the Thames are so far satisfactory, that there is no ground for disturbing the arrangements made under the Act of 1852, and that any attempt to do so would end in entailing a waste of capital, and an unnecessary charge upon the owners and occupiers of the metropolis." That, however, does not seem to have been the opinion of the Metropolitan Board when they promoted their Purchase and Supply Bills of 1878, nor does it seem to have been the view of the late Government, who introduced a Bill for the purchase of the Water Companies' undertakings, by agreement, in the first Session of 1880, and who, it is thought, must have contemplated some other measures for the supply of the metropolis than a mere continuance of water from the present sources, which are certainly distasteful to a large number of the consumers. We may not be prepared to go so far as the Rivers' Pollution Commissioners, who in their Sixth Report, in speaking of the water of the Kent Company which is drawn from deep wells in the chalk, said, "The supply of such water to the metropolis generally, would be a priceless boon, and would at once confer upon it absolute immunity from epidemics of cholera,"[1] but it is difficult on the other hand to bring ourselves to agree with Dr. Meymott Tidy, who, in his most valuable and interesting work upon the London Water Supply, says, "I venture to state broadly, and the analyses I now place before you justify me in the assertion, that the water supply to London—the healthiest city in the world—is as excellent in quality as it is liberal in quantity."[2] And again in writing in 1880 on the water supplied during the past year, he says, "I again repeat what I have said more than once before, that in my opinion no better sources of water can be found for the metropolis, considering all the facts of the case, than the Rivers Thames and Lea."[3] We need not, we think, go the length of the Rivers' Pollution Commissioners on the one hand, or of Dr. Tidy on the other; we may admit, as we believe it is a fact, that of late years the water supplied by London Companies has, owing to the increase of the

[1] *Sixth Report*, p. 275.

[2] *The London Water Supply; being a Report submitted to the Society of Medical Officers of Health on the Quality and Quantity of the Water supplied to the Metropolis during the past ten years.* London, 1878, p. 68.

[3] *Report for* 1880, p. 8. But Mr. Jabez Hogg, in his recent letters to *The Times* on Mr. Cross's "Water Trust Bill," assures us that the supply of drinking water from the rivers Lea and Thames is not, and cannot be, rendered satisfactorily safe, and he contends that the comparative purity for which chemistry vouches is shown, not only by the microscope, but by the returns of the Registrar-General, to be misleading, for the waters are the carriers of the seeds of disease.

storage capacity of their works, and the greater care which has been bestowed upon filtration, been better than it formerly was, and yet we do not feel bound to believe that the Thames water is a good water for a town supply. Indeed we do not believe that the Thames will long be continued as the source from which the metropolis will draw its water. We have seen that in the cases of Stockton, and Middlesborough, of Cheltenham, and Durham, Parliament has refused to sanction the supply of river water when there was a possibility of procuring other sources, and in each of these cases the towns have had recourse either to springs or the head waters of rivers. We believe that the reason in all these cases for the decision of Parliament was an impression that water was a carrier of disease, and that if sewage was poured into a river, and a water company draws its water from that river, there was a serious risk that disease might be communicated to the consumers of water so drawn. It seems absolutely necessary, for the purpose of understanding these questions aright, to draw a distinction between healthy and unhealthy sewage. Perhaps none of the diarrhœal diseases have been more thoroughly investigated than typhoid fever. Happily the visitations of cholera have been rare of late years, so that the opportunities of investigating the pathology and etiology of that disease have not been numerous;[1] but when it is

[1] See, however, as to the investigations of Professors Hallier and De Bary, as to the cholera-fungus, the results of which are abstracted in Mr. Simon's *Ninth Report of the Medical Officer of the Privy Council* (published in 1867), pp. 29, 512, 515.

remembered that upwards of seventy-three thousand persons have died of enteric fever in England alone during the last nine years, it will be seen that the opportunities of investigation have been numerous enough; for, of course, the number of deaths must be taken to be small in proportion to the number of persons affected by the disease, if any estimate of incidence and fatality can be founded on the Caterham and Redhill epidemic, where 352 persons suffered from the disease, but only twenty-one died of it. For a long time it was a question whether the poison of this disease was generated *de novo* from decaying organic matter, or whether it could only arise by continuous generation. The former view was held by the late Dr. Murchison, the latter by Dr. Budd, and we see that the most recent authority upon the subject, Dr. Cayley, thinks the weight of argument against the theory of the pythogenic origin of the disease, and believes that the continuous propagation of the disease is now universally admitted.[1] We believe that at one time the evils resulting from the infiltration of sewage into wells was doubted, exactly as the evils resulting from a similar contamination of rivers is at the present time. Let us quote some instances of poisoning from the infiltration of unhealthy sewage into well water, cases which bear upon the question of the specificity of the poison of these diseases. It is unnecessary, after the description already given of it, to refer again to Dr. Thorne Thorne's convincing report as to the Caterham epidemic.

[1] Croonian Lectures for 1880. *British Med. Journal*, 13th March, 1880.

"The water supply pipes of the town (Over Darwen)," says Dr. Cayley, "were leaky, and the soil through which they passed was soaked at one spot by the sewage of a particular house. No harm resulted until a young lady, suffering from typhoid fever, was brought to the house from a distant place; within three weeks of her arrival the disease broke out, and 1,500 persons were attacked." This case is interesting, as it would have been thought very difficult to infect water in pipes, even although the pipes were leaking at the time. It indicates, however, that persons may go on taking healthy sewage with impunity, and that the real danger occurs when unhealthy sewage has access to the water. Dr. Cayley goes on:—"Another well-marked instance occurred at Calne. A laundress occupied the middle one of a row of three houses supplied by one well into which the slops of the laundress's house leaked. She on one occasion received the linen soiled by the discharges of a case of typhoid fever, and after fourteen days cases occurred in all three houses. At Nunney, a number of houses received their water supply from a foul brook contaminated by the leakage of the cesspool of one of the houses, but no fever showed itself, till a man, ill with typhoid fever, came from a distance to these houses. In about fourteen days an outbreak of fever took place in all the houses." There can be no doubt then, that water can be, and very frequently is, the carrier of the causes of intestinal epidemic diseases; and it would seem that any water, into which sewage infected by the discharges of persons suffering from such diseases, has found its way, might be the means, if it was subsequently consumed in the course of diet, of propagating these specific diseases. It is upon this ground, as we understand it, that Dr. Frankland—than whom there is no greater chemical authority on any question affecting water supply—is so much opposed to the adoption of any water for supply into which sewage has been poured. It matters not, if we understand him, that chemical analysis cannot show that the water is an unwholesome one. If chemical analysis shows that the water has been previously contaminated by sewage, that is reason enough for rejecting it as a potable water. If there has been sewage in the water, it may have been unhealthy sewage, analysis cannot say it was or was not, and hence the risk. It seems to us, that possibly too great a reliance has been placed by many chemists upon chemical analysis. Common sense is revolted by water which is mixed with sewage, and although common sense is often far behind science, in many cases like children who stray before grown-up people, it runs before. But do not take this estimate of the value of analysis upon our authority. "The chemist cannot point to the specific infecting substance," but "can tell you whether the water is open to suspicion. Whether it is injurious to health can only be determined by physiological tests."[1] That is the opinion both of Dr. Frankland and of Dr. Alfred Hill.

[1] Cheltenham Water Bill, 1878, p. 167, Question 2872; and p. 162, Question 2809.

It is true that Dr. Tidy says: "All things which it is necessary to consider with respect to the purity of water, are attainable by chemical analysis."[1] But he admitted in another case that the discharges of a typhoid patient would be more unhealthy than the sewage of a healthy person,[2] and we do not understand him to hold that chemical analysis can distinguish between the excrementitious matter of healthy persons, and persons labouring under diarrhœal diseases. Mr. Crookes, who was called to give evidence in favour of the Wear water in the Durham case, said, "Chemical analysis would not show whether the constituents present were in such a form as to produce disease."[3] It is evident, then, that if the view we have alluded to be correct, that it is only the specific excreta of persons suffering from typhoid fever which give the disease, and that these may be conveyed to the individual in various ways, amongst which water is one of the most common, that nothing but a physiological test can determine whether sewage-infected water is specifically infected or not, for no chemical analysis can, as we said, distinguish healthy from unhealthy sewage. How then can it be that chemistry can, as Dr. Tidy seems to think, give you a sufficient answer as to the wholesomeness or unwholesomeness of water? We may point out that all the evidence we have quoted from Dr. Cayley's lectures is in entire conformity with

[1] Durham Water Bill, 1878, p. 32, Question 529.

[2] Stockton and Middlesborough Water Bill, 1876, p. 126, Question 1651.

[3] Durham Water Bill, 1878, p. 40, Questions 664, 666.

the view so often expressed by Dr. Frankland, that "normal sewage may be drunk with impunity,"[1] or as he put it on another occasion, "water mixed with healthy sewage is quite wholesome to drink; probably half the population of the country are drinking such water."[2] This is, too, the view of many other eminent sanitary authorities,[3] and Dr. Odling, one of them, in the same case said: "Ordinarily speaking, I should have no objection to drinking the water of Darlington, knowing that the sewage of Barnard Castle was poured into it; but if I heard that there was an outbreak of fever at Barnard Castle I should be shy," and he added, "there is a certain amount of risk which ought to be avoided."[4] The difficulty of course arises as to the physiological tests, which are the only indications of the presence of the specific poison in the water. However, these experiments have been made in the past at frightful cost, in relation to some waters. There is one instance which has been often quoted. We quote the case in the words of Dr. Alfred Hill. "In the cholera visitations of 1849 and 1854, when certain parts of London were supplied with the Thames water, cholera was evidently produced by drinking it.

[1] Cheltenham Water Bill, 1878; Evidence, p. 170, Question 2910.

[2] Stockton and Middlesborough Bill, 1876; Commons, Evidence, p. 173, Question 534. See also Cheltenham Water Bill; Evidence of Dr. Alfred Hill, p. 162, Question 2809.

[3] See Stockton and Middlesborough Water Bill, 1876; Commons, Evidence of Dr. Alfred Hill, p. 181, Question 624; Cheltenham Water Bill, 1878; Dr. Hill, p. 160, Question 2767.

[4] Stockton and Middlesborough Water Bill, 1876, p. 184, Questions 668, 669.

In 1849, when the two companies, for instance the Southwark Company and the Lambeth Company, drew the water below Battersea Bridge—that is to say within the tidal influence, and therefore within the influence of pollution from the sewers—the districts supplied by both those companies suffered very much from cholera, and they suffered equally. Then subsequently in the year 1854, when the Southwark and Lambeth Companies drew their supplies from different parts of the river, Southwark out of the sewage pollution of the river, and Lambeth above Teddington—above that influence—then it was found that there was a very high mortality from the cholera in the district supplied by the Southwark Company while there was a very low mortality from the same disease in the district supplied by the Lambeth Company."[1] Perhaps another good illustration may be taken from the case of the town of Doncaster. "The Don flows from Sheffield and Rotherham to Doncaster. In 1866, according to Dr. Sieman's report, there was cholera from July to October in Sheffield; the epidemic commenced in July, was very bad in August and September, and ceased about the 10th of November, which was about a fortnight after it had ceased at Sheffield. I think that is a very clear illustration of the effect of the cholera on infected sewage carried down a distance of between fifteen and twenty miles from one town to another and carrying

[1] Cheltenham Water Bill, 1878; Evidence, p, 156, Questions 2707, 2708. We believe that in the one district the mortality per 10,000 was 37, while in the other it was 130, and there were 4,000 deaths in all.

the disease with it."[1] Dr. Frankland adds as to this case:—"I know the case very well myself. The outbreak of cholera occurred a little earlier in Sheffield than it did in Doncaster; the people of Doncaster drank the sewage of the people of Sheffield, and they got the cholera."[2] Another well-known physiological experiment was made abroad. It has been more than once referred to by Dr. Frankland in evidence,[3] but as his description of it was necessarily short, we give the details of this case from Dr. Cayley's Croonian Lecture.

"Lausen is a village through which I have no doubt most of my hearers have passed, as it lies on the railway between Basle and Olten, shortly before coming to the great Hauenstein tunnel. It is situated in the Jura, in the valley of the Ergolz, and consists of 103 houses with 819 inhabitants; it was remarkably healthy, and resorted to on that account as a place of summer residence. With the exception of six houses, it is supplied with water by a spring with two heads which rises above the village, at the southern foot of a mountain called the Stockhalder, composed of oolite. The water is received into a well-built covered reservoir, and is distributed by wooden pipes to four public fountains, whence it is drawn by the inhabitants. Six houses had an independent supply, five from wells, one from the mill dam of a paper factory. On August 7th, 1872, ten inhabitants of Lausen, living in different

[1] Cheltenham Water Bill, 1878, p. 156, Question 2710.

[2] *Ibid*, p. 170, Question 2916.

[3] See Stockton and Middlesborough Water Bill, 1876; Evidence p. 171, Question 491; and Wakefield Water Bill, 1876, p. 74, Question 1079.

houses, were seized by typhoid fever, and during the next nine days fifty-seven other cases occurred, the only houses escaping being those six which were not supplied by the public fountains. The disease continued to spread, and in all 130 persons were attacked, and several children who had been sent to Lausen for the benefit of the fresh air, fell ill after their return home. A careful investigation was made into the cause of this epidemic, and a complete explanation was given. Separated from the valley of the Ergolz, in which Lausen lies, by the Stockhalder, the mountain at the foot of which the spring supplying Lausen rises, is a side valley called the Furlenthal, traversed by a stream, the Furlenbach, which joins the Ergolz just below Lausen, the Stockhalder occupying the fork of the valleys. The Furlenthal contained six farm-houses, which were supplied with drinking water, not from the Furlenbach, but by a spring rising on the opposite side of the valley to the Stockhalder. Now there was reason to believe, that, under certain circumstances, water from the Furlenbach found its way under the Stockhalder into one of the heads of the fountain supplying Lausen. It was noticed that when the meadows on one side of the Furlenthal were irrigated, which was done periodically, the flow of the water in the Lausen spring was increased, rendering it probable that the irrigation water percolated through the superficial strata and found its way under the Stockhalder by subterranean channels in the limestone rock. Moreover, some years before, a hole on one occasion formed close to the Furlenbach by the sinking in of the superficial strata, and the stream became diverted into it and disappeared, while shortly afterwards the spring at Lausen began to flow much more abundantly. The hole was filled up, and the Furlenbach resumed its usual course. The Furlenbach was unquestionably contaminated by the privies of the adjacent farm-houses, the soil pits of which communicated with it. Thus from time immemorial, whenever the meadows of the Furlenthal were irrigated, the contaminated water of the Furlenbach, after percolation through the superficial strata, and a long underground course, helped to feed one of the two heads of the fountain supplying Lausen. The natural filtration, however, which it underwent, rendered it perfectly bright and clear, and chemical examination showed it to be remarkably free from organic impurities; and Lausen was extremely healthy and exempt from fever. On June 10th one of the peasants of the Furlenthal fell ill with typhoid fever, the source of which was not clearly made out, and passed through a severe attack with relapses, so that he remained ill all the summer; and on July 10th a girl in the same house, and in August a boy were attacked. Their dejections were certainly in part thrown into the Furlenbach; and moreover, the soil-pit of the privy communicated with the brook. In the middle of July the meadows of Furlenthal were irrigated as usual for the second hay crop, and within three weeks this was followed by the outbreak of the epidemic at Lausen.

"In order to demonstrate the connection between the water supply of Lausen and the Furlenbach, the following experiments were performed. The hole I mentioned above, as having on one occasion diverted the Furlenbach into the presumed subterranean channels under the Stockhalder, was cleared out, and 18 cwt. of salt were dissolved in water and poured in, and the stream again diverted into it. The next day salt was found in the spring at Lausen. Fifty pounds of wheat flour were then poured into the hole, and the Furlenbach again diverted into it; but the spring at Lausen continued quite clear, and no reaction of starch could be obtained, showing that the water must have found its way under the Stockhalder, in part by percolation through the porous strata, and not by distinct channels."[1]

But although the obvious inferences from these cases are not denied, it is said that all the cases upon record only show that diarrhœa, cholera, and typhoid fever are conveyed by water where it has been delivered through close or confined pipes; but where the excreta of persons suffering from these diseases are passed into open rivers and become mixed with large bodies of running water, where it is freely exposed to the air and the various other oxidising agencies, it is rendered inert, and passes away with the other sewage by oxidation. Dr. Odling described this view very clearly in his evidence upon one occasion. "There are several well-established cases," he said, "in which persons have suffered from cholera or typhoid fever, through drinking water into which the discharges of patients suffering from cholera or typhoid fever have been directly poured; but there

[1] See *British Medical Journal*, 13th March, 1880.

is no case within my knowledge, in which an accident of that kind has occurred, where there has been anything like a run (down a river) of a dozen or even half a dozen miles."[1] We confess we cannot quite reconcile this opinion with the evidence he gave in the Stockton and Middlesborough case, which we referred to above, in which he said he would be shy of drinking Darlington water if he knew there was fever at Barnard Castle, which was seventeen miles above the Company's intake. However it puts the point clearly, and there can be very little doubt that there is one great difficulty in the way of saying that the poison of typhoid fever conveyed through running water, before it is taken into a Company's pipes, is the same thing as the poison of typhoid fever when it has not been exposed to the oxidising agents of a river course—and that difficulty is the experience of the health of London. If the poison is not rendered inert, how is it that typhoid fever is sporadic, instead of being constantly epidemic in London, seeing that we are drinking water infected by the sewage of 800,000 people, and that enteric fever is always more or less prevalent somewhere in the Thames Valley above the Companies' intake? This consideration seems to weigh with Dr. Cayley, who apparently agrees with those who think that running water will oxidise all the harm out of the excreta of typhoid patients.[2] We cannot understand why, if such is his view, he should lay it down as a rule

[1] Durham Water Bill, 1878, p. 43, Question 715.

[2] Croonian Lecture, *British Medical Journal*, 20th March.

in hygiene, as he does, "that human excrements should under no circumstances be mixed with drinking water, however completely they may be subsequently removed by filtration or rendered innocuous by oxidation," and why he should protest against a dictum "that water containing less than a certain proportion of organic impurity, is practically wholesome and fit for drinking, irrespective of its original source." But we believe that the evidence that oxidation does render the germs of disease inert, is not so conclusive as he seems to think. In the first place we have mentioned the well-authenticated case in which the contagion of cholera was carried by the River Don from Sheffield to Doncaster.[1] But further, does not irrigation perform for sewage exactly the same office that a run down a shallow river would? Does it not oxidise the sewage matter? And yet does not Dr. Cayley warn people against "trusting to irrigation and downward filtration as a means of purifying water?" Besides, in the Lausen case there seems not only to have been artificial irrigation of the meadows, but natural filtration through porous strata and percolation through rocks, which would, we know, get rid of the impurities from the farm-house privies in exactly the same way as water flowing down a tumbling stream would,[2] and yet the typhoid poison got through the meadows, the surface strata, and the mountain Stockhalder, and poisoned the

[1] *Ante*, p. 78.

[2] Stockton and Middlesborough Water Bill, 1875; Evidence of Dr. Letheby, p. 85, Question 1503.

people at Lausen. Again, it seems certain, although Mr. Michael in his *Address on Health* says "that the whole evidence leads to the conclusion that such epidemics [epidemics of cholera and diseases of the like type] have always travelled up stream from the outfall of the river to its source,"[1] that cholera travels as often down stream as up. We have mentioned one case in which it went down, and Dr. Hill, in his Evidence on the Cheltenham Bill, states that it travels up river with the traffic and down the river with the water.[2] The difficulty of getting authentic statistics as to the real spread of cholera is very great, but our own impression is that they bear out Dr. Hill's statement.

But there are other reasons for thinking that the view taken by those who hold that a few miles of running water will get rid of the germs of intestinal epidemic diseases, is scarcely warranted. No doubt there is great weight of opinion on each side. Thus Dr. Meymott Tidy has been a consistent advocate of this view, and upon the 18th of March he read a paper to the Chemical Society upon the subject. He may have strengthened the evidence for this view in the

[1] *Address on Health*, 1879, p. 28.

[2] Cheltenham Water Bill, 1878, p. 164, Questions 2841 *et seq.* It is well known that cholera has a preference for low situations and particularly for the low-lying flats on banks of rivers, especially too where the inhabitants are supplied with the water from streams, which seem to give a strong reason for supposing that water, even in open river channels, is a carrier of the poison of this disease. In Dr. Snow's work on the *Communication of Cholera*, 2nd Edition, 1855, and also the Reports of the Registrar-General of England on Cholera of 1848–9, and his 17th Annual Report for 1854.

eyes of others, but we do not think he can, by any recent investigations, have increased the tenacity of his own conviction. In giving evidence before the Committee on the Stockton and Middlesborough Bill, 1876, he said:—"I should say if sewage were mixed with twenty times its bulk of water, and had a run of twenty miles, you would find no sewage, that is to say, the sewage is not to be found by chemical means;"[1] and in another place, "I feel perfectly convinced that the whole of the sewage of Barnard Castle would be oxidised by such a run, by a very much less run than seventeen miles;"[2] and in a third place he said, "I have no hesitation in saying that if there was choleraic or typhoid matter entering that water from those people, even supposing there was an epidemic, I should have no hesitation myself in drinking the water at a distance of eight or ten miles from the place where it entered."[3] In other cases he expressed equally strong and confident views.[4] In the Cheltenham case Mr. Crookes, who, like Dr. Tidy, admits that such diseases can be propagated by water, took a somewhat similar view as to the effects of a run down stream upon sewage.[5] And Dr. Odling, somewhat inconsistently, we venture to think, with the evidence he gave in the Stockton and Middlesborough

[1] Evidence, p. 125, Ques. 1636. [2] Evidence, p. 124, Ques. 1629.

[3] Evidence, p. 166, Question 1644.

[4] Cheltenham Water Bill, 1878, p. 106, Question 1427; p. 108, Question 1464; and p. 109, Question 1465; Durham Water Bill, 1878, p. 32, Question 528.

[5] Cheltenham Water Bill, 1878, p. 113, Question 1531.

case, when speaking of the sewage and organic substances, said, "Though noxious when put in at Worcester, sixteen miles above, they are innocuous when they arrive at this point" (the Company's intake at Tewkesbury).[1] Mr. Hawkesley, speaking, in the same case, of sewage in small quantity poured into a large body of water, said, "It cannot by any possibility continue to be sewage even a couple of miles. It is utterly impossible. It is all burnt up by the oxygen in the water, and utterly destroyed." [2]

On the other hand, Dr. Hill thought that the facts were against Mr. Hawkesley's statement.[3] The Rivers Pollution Commissioners stated that although oxidation did take place in rivers, there was no river in England long enough to effect the destruction of sewage by this means, and Dr. Frankland repeated that statement in his evidence before the Committee on the Cheltenham Water Bill, 1878,[4] and in another case, upon being asked, what would be a sufficiently long run for such a purpose, he said, "Not less than 200 miles." [5] That in a run of sixteen miles in the Severn, the sewage of Worcester would not be destroyed, he was certain. He said, "It is a matter of demonstration;" and he stated that Blackburn puts its sewage into the Darwen, and that he had traced it thirteen miles below that town. Although some oxidation had been effected,

[1] Cheltenham Water Bill, 1878, p. 133, Question 1751.

[2] *Ibid*, p. 91, Question 1210. [3] *Ibid*, p. 156, Question 2713.

[4] Evidence, p. 166, Question 2867.

[5] Stockton and Middlesborough Water Bill, 1876; Commons, Evidence, p. 174, Question 520.

nearly the whole of the sewage was still in the water. And his experience was the same in the Irwell, below Manchester, in the Mersey, and in the Thames below Reading, his conclusion being that "the oxidation in any moderate flow of fifteen or twenty miles is very slight indeed."[1] It would be easy to accumulate opinions and evidence upon both sides of this disputed question, but we may mention the opinion of Professor Way, who believes in a considerable amount of oxidation in rivers, but points to the difficulty in the way of the confident consumption of water in the manner that Dr. Tidy spoke of, viz., that it is impossible to tell when the oxidation is completed.[2]

But it is unnecessary to go further with our quotations, for it seems to us quite possible to suppose that the sewage may have been got rid of by oxidation, and at the same time to hold that the specific poison, which is admitted to be the cause of diarrhœal diseases, although it passes into the water with the sewage, is not destroyed at the same time, or by the same means. We cannot help thinking that the fact that decaying vegetable and animal matter is got rid of by a longer or shorter run down a shallow river, will not prove that living matter will be got rid of, or, as Dr. Cayley puts it, be rendered inert by a similar process. There is very strong evidence in favour of the theory that diseases are propagated by specific germs. The ingenious question which is usually put

[1] Cheltenham Water Bill, 1878; Evidence, p. 166, Question 2867.
[2] *Ibid.* p. 185, Question 3119; and p. 186, Question 3126.

by counsel to any believer in the germ theory of disease, whether he has ever seen a germ, may seem pertinent, but it really has nothing to do with the subject. There are many things which we believe and know to exist, and which we have not seen. We believe light to be propagated and radiated through and by means of an imponderable ether, and that not because we have seen it, but because all the facts with which we are acquainted can best be explained by the supposition of such a medium. But there are a great many reasons for supposing that, just as wounds used to go wrong in consequence of their non-protection from germs, which are now kept at bay by the antiseptic system of surgery—there may be analogous germs which grow and multiply their kind when placed in favourable conditions. But the evidence is not merely that the theory of disease, and all the facts in connection with it, can be better explained by supposing the existence of germs than by any other supposition. We must reason in this matter from analogy, and when we find that an analogous disease has been found to depend upon the existence and the communication of a germ, and that that germ has not only been seen, but named; and that when the *Bacillus anthracis* is administered to an animal it will infallibly produce splenic fever in it; we have some reason for believing in the existence of germs in the diarrhœal diseases with which we have most to do, in considering questions of water supply. But again it must be remembered that other zymotic diseases, such as small-pox, cow-pox, glanders, sheep-pox, were found by Chaveau to be due to organised granules or germs, and that this view has been confirmed by Dr. Burdon Sanderson. There seem then to be very strong reasons for supposing that cholera, typhoid, and diarrhœa, are also due to germs, although up to the present time they have not been seen.[1] Many of Dr. Burdon Sanderson's researches were physiological, and while applicable to the specific diseases of animals, are inapplicable to the diseases of man. And we have to trust to the great vivisectionist, Disease, for the experiments which enable us, in such cases, to arrive at a conclusion as to the cause of these ailments. There can then be little question, we think, that water is not an unfavourable condition to the germs of these diarrhœal diseases. This is not only proved by the numerous cases we have referred to, but by a great concurrence of testimony on the point. Indeed we may say, that water seems to be one of the best carriers of these diseases. That air is not unfavourable to the continued activity of the germ is certain from many of the cases referred to by Dr. Cayley, and that even boiling does not destroy them is evident from the three most interesting cases collected and recorded by him of poisoning by cooked meat at Andelfingen in 1839, at Thalweil in 1845, and at Kolten in June, 1878.[2] If, then, germs can survive such unfavourable

[1] The germs of relapsing fever, too, were discovered by Dr. Obermeier of Berlin, and the subject has been investigated by Professor Cohn. See Dr. Alfred Carpenter's "Remarks upon the First Principles of Sanitary Work." *British Medical Journal*, Oct. 25th, 1879, p. 646.

[2] See Croonian Lectures, Lecture I. Published in *British Medical Journal*, 28th March, 1880.

conditions as these, is there any reason to suppose that they would be burnt up by the oxidation in a river in running a few miles? Then, as we understand it, oxidation does not apply to living matter, and that is the view taken by various authorities. "Living matter," says Dr. Alfred Hill, "does not get oxidised by flowing down a stream any more than a fish,"[1] and again seeing that "it is not decomposing animal matter which is prejudicial, but actually living matter in the water,"[2] "mere dilution by water does not deprive it of its dangerous qualities."[3] And Dr. Frankland says, "I do not think it possible by any practicable means that have been suggested, so to purify sewage as to guarantee its freedom from these elements of disease—these germs of disease;"[4] and again, "Twenty or thirty, or even fifty or sixty miles makes very little difference to those specific germs."[5] We cannot, under these circumstances, wonder at the opinion of these two eminent observers, that if a spoonful of unhealthy sewage is put into the Thames at Oxford it may poison some persons in London;[6] but, at the same time, we cannot but wonder, that under these circumstances epidemics of typhoid and diarrhœa are not of more frequent, are

[1] Cheltenham Water Bill, 1878, p. 162, Question 2805.

[2] Wakefield Water Bill, 1874, p. 177, Question 2785; Evidence of Dr. Frankland.

[3] Cheltenham Water Bill, 1878; Dr. Hill's Evidence, p. 162, Question 2806.

[4] *Ibid*, p. 168, Question 2882.

[5] *Ibid*, p. 171, Question 2924.

[6] *Ibid*, Evidence of Dr. Frankland, p. 171, Question 2923; Evidence of Dr. Alfred Hill, p. 160, Question 2772.

not of constant occurrence in the metropolis. If the chance-spilt excrement of one man in the Caterham well could cause such an epidemic as that to which we have referred, how is it that London is so free from epidemics as it is, seeing that its main supply of water is drawn from the Thames? Dr. Tidy in one case stated, that the death-rate in the parts of London supplied by the deep chalk well waters of the Kent Water Company, is greater than the death-rate of places supplied with the water of the Thames or Lea, and that all the zymotic diseases, typhoid, and scarlet fever, are also higher in those first-mentioned districts.[1] We see, however, that he does not speak thus strongly in his work on *The London Water Supply*, but says that he "has failed to discover any difference worth noting in death-rates, or any evidence whatsoever that any special class of disease has been prevalent from drinking the water of the Thames or Lea, or absent from the use of the chalk water."[2] And this fact is, it must be confessed, somewhat difficult of explanation. Dr. Cayley seems to attribute most of the sporadic cases of typhoid fever which are to be met with in London, to emanations from the drains and to the insanitary conditions which favour the access of the poison in this way to its victims; but we believe that other observers are of opinion, that a larger proportion of these cases is to be traced to the supply of water than Dr. Cayley seems to think; and we may say that

[1] Durham Water Bill, 1878, p. 32, Question 532.

[2] Pages 68, 69.

Dr. Cayley does not give many or any cases of poisoning by sewer-gas, while he does give many, of the conveyance of the poison by means of water. Still there are many facts in this relation which seem to be inexplicable upon any established hypothesis, and we must be content to wait for the fuller revelation which may be reached through long bills of mortality in time to come. We would, however, repeat here as all-important, a quotation we have already made from Dr. Cayley's Croonian Lecture, "I think these two instances [the Caterham and Lausen cases] are sufficient of themselves to serve as a warning against trusting to irrigation and downward filtration as a means of purifying water, and also against the dictum that water containing less than a certain proportion of organic impurity is practically wholesome and fit for drinking, irrespective of its original source. It ought, I think, to be laid down as a rule of hygiene that human excrements should under no circumstances be mixed with drinking water, however completely they may be subsequently removed by filtration or rendered innocuous by oxidation. Of course in the case of London this can only be looked upon as an ideal to be realised in some distant future; but with less than this we ought not to rest satisfied."[1]

We have not thought it necessary to deal with many questions indirectly connected with our subject, as, for instance, the important question whether waterworks

[1] *British Medical Journal*, 20th March, 1880.

and the supply of water should be in the hands of private enterprise or of public sanitary authorities. We have not dealt with that matter here, because we dwelt upon it at some length in another place.[1] The question has also been treated by Mr. Michael in his *Address on Health.*[2] We may, however, say a word, before concluding, as to the way in which water companies, where the supply is in their hands, raise their capital. It is well known that Gas Companies, under an order of the House of Commons which became a Standing Order in 1877,[3] when they seek to increase their capital, are no longer allowed to distribute the new capital amongst their shareholders at par, as they used to do, but must sell the new shares at auction, and any premium realised upon the shares goes into the capital of the undertaking, but does not bear dividend, and consequently inures to the benefit of the consumer. With this clause, which is now, unless there are very special circumstances, inserted in all Gas Acts, is usually associated a sliding-scale clause, which enables the Company, if it reduces the price of gas to the consumers under a certain fixed price, called the "standard price," to divide more interest, every penny of reduction entitling the Company to divide one-quarter per cent. more of dividend.[4]

[1] See *The Compulsory Purchase of Companies' Undertakings by Corporations.*

[2] See pp. 31, 32.

[3] Standing Order, 188*a*.

[4] See article on "Auction Clauses and Sliding-Scale," in *Railway Times*, 21st July, 1877.

There may be reasons why these clauses should be imposed upon Gas Companies and not upon Water Companies, but these are not obvious to some persons, and there are cases in which the auction clauses have been inserted in the Water Bills, and cases in which they have been asked for in the interest of the consumers, and refused. This is the experience of the leader of the Parliamentary Bar, Sir Edmund Beckett, Q.C., than whom no one is more familiar with Parliamentary precedent. "In 1854 the Nottingham Waterworks' Company adopted, I do not know under what circumstances, the auction clauses. In 1874 they desired to raise more money, and the Corporation endeavoured in both Houses to have these clauses applied to that capital, and did not succeed. Not only did the Corporation of Nottingham fail, but the Corporation of Sunderland failed a few years ago, the Corporation of Liverpool failed, and the Corporation of Chesterfield also failed; those are the only cases where the auction clauses once existed, as I told you, for some reasons temporarily or otherwise, and nevertheless when all these companies—in one case both gas and water—came to Parliament for increase of capital, the Corporations failed in persuading Parliament to compel them to sell their shares by auction."[1] But in that case—in connection with which the speech we have quoted from was delivered—the Committee of the

[1] Nottingham Water Bill, 1878; Speech of Sir Edmund Beckett, Q.C., p. 6.

House of Commons directed the auction clauses to be inserted in the Bill.[1]

Every reader will remember the story with which Macaulay begins one of his essays, of the pious Brahmin who had made a vow that he would sacrifice a sheep, and who went forth to buy one, when he was waylaid by a neighbour who had come to know of his purpose, and was in league with other crafty-minded men to deceive the Brahmin, who offered him an ugly cur—abhorred as a sacrifice,—saying it was the sheep he required. Dispute arose as to whether this mangy animal was a sheep of fine fleece or a mongrel cur, when one of the conspirators came up and swore that the dog was a sheep, and praised the Gods for the lucky chance which had saved him the trouble of going to the sheep-market, whither, it appeared, he was bound to buy a sheep. "When the Brahmin heard this," says Macaulay, "his mind wavered to and fro. 'Sir,' said he to the new-comer, 'take heed what thou doest; this is no sheep, but an unclean cur.' 'Oh Brahmin,' said the other, 'thou art drunk or mad.' And then the third conspirator came up and would have it that the dog was a sheep, so that at last the Brahmin was over-persuaded, purchased the dog, offered it up to the Gods, who, being angry at the unclean sacrifice, smote him with sore disease in all his joints." Macaulay uses the story merely for a literary purpose; but might it not be used in a sanitary connection? Have not men been willing to

[1] Minutes of Proceedings, 22nd March, 1878, p. 113.

sacrifice much to have the blessings of health upon their households; and have they not gone out to inquire of the College of Physicians what they must do to be saved from disease; and have not these medical savants told them that they must have a splendid system of drains spreading into every house, and that they must have water laid on into every cistern? Have not these physicians, in the wide confederacy of ignorance, insisted that those poisonous snakes, drains, and those other serpents, water-pipes, were salutary metal serpents, upon which we had only to look favourably and live; and have not we, believing them, taken these vipers into our households and been smitten with sore diseases in all our joints?

We do not exaggerate. Dr. Cayley says that Sir John Harrington, who in the reign of Elizabeth invented water-closets, is responsible for most of the typhoid fever we suffer from; and does he not in the same lecture refer to the waste-pipes from our cisterns, which with open mouths pour the poison of the sewer into our cup? These considerations seem to be sufficient reason for scrupulous care as to the choice and management of our water sources and supply, and must be our excuse for having offered these remarks upon a subject, the importance of which can scarcely be exaggerated.

APPENDIX.

APPENDIX.

WAKEFIELD WATERS.

WAY AND OGSTON.

In 100,000 *parts.*

	Wath Main Collery.		Town supply. April 9.
	March 30.	April 16.	
Chlorine	8·84	4·79	2·47
Sulphuric Acid	3·11	4·10	9·11
Lime	4·96	5·60	5·70
Magnesia	3·23	3·37	2·67
Silica, Oxide of Iron, &c.	0·29	0·39	0·44
Soda	16·34	11·74	7·70 (Soda and Carbonic Acid together)
Carbonic Acid (as Carbonates)	11·34	11·16	
Loss in burning (Organic Matter, &c.)	1·71	2·86	2·28
	49·82	44·01	30·37
Ammonia	·009	·010	·005
Albuminoid Ammonia	·001	·004	·006
Hardness { Temporary	14·0	13·3	6·0
Hardness { Permanent	2·1	2·4	11·7
TOTAL	16·1	15 7	17·7
Carbonate of Soda	10·63	7·34	None.

CHEMICAL DEPARTMENT, SOUTH KENSINGTON MUSEUM.

Results of Analysis expressed in Parts per 100,000.

TABLE A.

Number of Sample.	Description.	Total solid impurities.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous sewage or animal contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Carbonate of Soda.	Magnesia.	Lime.	Silica.	Peroxide of Iron.
	Wath main Water.																
1876 March 5	From Culverts...	46·40	·088	·016	·018	0	·031	0	9·00	11·8	3·9	15·7	14·35	3·10	4·72	1·56	·10
April 9	From Culverts...	36·60	·083	·032	·012	0	·042	0	4·15	11·7	4·6	16·3	6·99	3·70	4·91	1·80	·26

Results of Analysis expressed in Parts per 100,000.

Water from	Total solid impurities.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous sewage or animal contamination.	Chlorine.	Hardness.		
									Temporary.	Permanent.	Total.
Glasgow (Loch Katrine)	3·20	·192	·008	·001	·0	·009	0	·79	—	—	1·0
Thirlmere	2·66	·194	·004	·003	·002	·008	0	·52	—	—	·7
Lancaster, Millstone grit	4·58	·129	·022	·001	0	·023	0	·99	—	—	·9
London, West Middlesex, Thames, filtered	26·40	·125	·021	0	·155	·176	12·30	1·45	—	—	19·3
Liverpool, Red-sandstone well	26 40	·020	·020	0	·416	·436	38·40	2·68	4·0	9·6	13·6
Bath, Spring-water from Oolite	30·76	·009	·004	0	·130	·134	980	1·46	21·8	5·4	27·2
Balder } Authorised sources for Stockton	8·00	·305	·022	0	0	·022	0	1·60	0·2	4·0	4·2
Lune } and Middlesborough	9·24	·245	·014	0	0	·014	0	1·27	0·0	6·0	6·0

EDINBURGH AND DISTRICT WATER BILL, 1871.

Summary abstract of Table showing quality of Water Supply as regards Hardness and Death-rates in sixty-five English and Scotch Cities and Towns.

Degrees of Hardness.	Average Death-rate per 1,000 Population.	Average degree of Hardness.
Over 10	21·9	16·0
10 to 6	24·9	8·0
6 to 2	26·3	3·8
2 and under	28·5	1·3

BEDFORD STREET, COVENT GARDEN, LONDON,
December, 1879.

MACMILLAN & CO.'S CATALOGUE of WORKS in MATHEMATICS and PHYSICAL SCIENCE; including PURE and APPLIED MATHEMATICS; PHYSICS, ASTRONOMY, GEOLOGY, CHEMISTRY, ZOOLOGY, BOTANY; and of WORKS in MENTAL and MORAL PHILOSOPHY and Allied Subjects.

MATHEMATICS.

Airy.—Works by Sir G. B. AIRY, K.C.B., Astronomer Royal:—

ELEMENTARY TREATISE ON PARTIAL DIFFERENTIAL EQUATIONS. Designed for the Use of Students in the Universities. With Diagrams. New Edition. Crown 8vo. 5*s*. 6*d*.

ON THE ALGEBRAICAL AND NUMERICAL THEORY OF ERRORS OF OBSERVATIONS AND THE COMBINATION OF OBSERVATIONS. Second Edition. Crown 8vo. 6*s*. 6*d*.

UNDULATORY THEORY OF OPTICS. Designed for the Use of Students in the University. New Edition. Crown 8vo. 6*s*. 6*d*.

ON SOUND AND ATMOSPHERIC VIBRATIONS. With the Mathematical Elements of Music. Designed for the Use of Students of the University. Second Edition, revised and enlarged. Crown 8vo. 9*s*.

A TREATISE ON MAGNETISM. Designed for the Use of Students in the University. Crown 8vo. 9*s*. 6*d*.

Ball (R. S., A.M.).—EXPERIMENTAL MECHANICS. A Course of Lectures delivered at the Royal College of Science for Ireland. By ROBERT STAWELL BALL, A.M., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland (Science and Art Department). Royal 8vo. 16*s*.

"*We have not met with any book of the sort in English. It elucidates instructively the methods of a teacher of the very highest rank. We most cordially recommend it to all our readers.*"—Mechanics' Magazine.

5,000. 12. 79

Merriman.—ELEMENTS OF THE METHOD OF LEAST SQUARES. By MANSFIELD MERRIMAN, Professor of Civil and Mechanical Engineering, Lehigh University, Bethlehem, Penn., U.S.A. Crown 8vo. *7s. 6d.*

Morgan.—A COLLECTION OF PROBLEMS AND EXAMPLES IN MATHEMATICS. With Answers. By H. A. MORGAN, M.A., Sadlerian and Mathematical Lecturer of Jesus College, Cambridge. Crown 8vo. cloth. *6s. 6d.*

Newton's Principia.—4to. cloth. *31s. 6d.*

It is a sufficient guarantee of the reliability of this complete edition of Newton's Principia *that it has been printed for and under the care of Professor Sir William Thomson and Professor Blackburn, of Glasgow University.*

Parkinson.—A TREATISE ON OPTICS. By S. PARKINSON, D.D., F.R.S., Fellow and Tutor of St. John's College, Cambridge. Third Edition, revised and enlarged. Crown 8vo. cloth. *10s. 6d.*

Phear.—ELEMENTARY HYDROSTATICS. With Numerous Examples. By J. B. PHEAR, M.A., Fellow and late Assistant Tutor of Clare Coll. Cambridge. Fourth Edition. Cr. 8vo. cloth. *5s. 6d.*

Pirrie.—LESSONS ON RIGID DYNAMICS. By the Rev. G. PIRRIE, M.A., Fellow and Tutor of Queen's College, Cambridge. Crown 8vo. *6s.*

Puckle.—AN ELEMENTARY TREATISE ON CONIC SECTIONS AND ALGEBRAIC GEOMETRY. With numerous Examples and Hints for their Solution. By G. HALE PUCKLE, M.A. Fouth Edition, enlarged. Crown 8vo. *7s. 6d.*

Rayleigh.—THE THEORY OF SOUND. By LORD RAYLEIGH, F.R.S., formerly Fellow of Trinity College, Cambridge. 8vo. Vol. I. *12s. 6d.*; Vol. II. *12s. 6d.* [Vol. III. *in preparation.*

Reuleaux.—THE KINEMATICS OF MACHINERY. Outlines of a Theory of Machines. By Professor F. REULEAUX. Translated and edited by A. B. W. KENNEDY, C.E, Professor of Civil and Mechanical Engineering, University College, London. With 450 Illustrations. Royal 8vo. *20s.*

Routh.—Works by EDWARD JOHN ROUTH, M.A., F.R.S., late Fellow and Assistant Tutor of St. Peter's College, Cambridge; Examiner in the University of London :—

AN ELEMENTARY TREATISE ON THE DYNAMICS OF THE SYSTEM OF RIGID BODIES. With numerous Examples. Third Edition, enlarged. 8vo. *21s.*

Routh—*continued.*

STABILITY OF A GIVEN STATE OF MOTION, PARTICULARLY STEADY MOTION. The Adams' Prize Essay for 1877. 8vo. 8*s.* 6*d.*

Tait and Steele.—DYNAMICS OF A PARTICLE. With numerous Examples. By Professor TAIT and Mr. STEELE. Fourth Edition, revised. Crown 8vo. 12*s.*

Thomson.—PAPERS ON ELECTROSTATICS AND MAGNETISM. By Professor SIR WILLIAM THOMSON, F.R.S. 8vo. 18*s.*

Todhunter.—Works by I. TODHUNTER, M.A., F.R.S., of St. John's College, Cambridge :—

"*Mr. Todhunter is chiefly known to students of mathematics as the author of a series of admirable mathematical text-books, which possess the rare qualities of being clear in style and absolutely free from mistakes, typographical or other.*"—Saturday Review.

A TREATISE ON SPHERICAL TRIGONOMETRY. New Edition, enlarged. Crown 8vo. cloth. 4*s.* 6*d.*

PLANE CO-ORDINATE GEOMETRY, as applied to the Straight Line and the Conic Sections. With numerous Examples. New Edition. Crown 8vo. 7*s.* 6*d.*

A TREATISE ON THE DIFFERENTIAL CALCULUS. With numerous Examples. New Edition. Crown 8vo. 10*s.* 6*d.*

A TREATISE ON THE INTEGRAL CALCULUS AND ITS APPLICATIONS. With numerous Examples. New Edition, revised and enlarged. Crown 8vo. cloth. 10*s.* 6*d.*

EXAMPLES OF ANALYTICAL GEOMETRY OF THREE DIMENSIONS. New Edition, revised. Crown 8vo. cloth. 4*s.*

A TREATISE ON ANALYTICAL STATICS. With numerous Examples. New Edition, revised and enlarged. Crown 8vo. cloth. 10*s.* 6*d.*

A HISTORY OF THE MATHEMATICAL THEORY OF PROBABILITY, from the Time of Pascal to that of Laplace. 8vo. 18*s.*

RESEARCHES IN THE CALCULUS OF VARIATIONS, Principally on the Theory of Discontinuous Solutions: An Essay to which the Adams' Prize was awarded in the University of Cambridge in 1871. 8vo. 6*s.*

Coal: ITS HISTORY AND ITS USES. By Professors GREEN, MIALL, THORPE, RÜCKER, and MARSHALL, of the Yorkshire College, Leeds. With Illustrations. 8vo. 12*s.* 6*d.*

"*It furnishes a very comprehensive treatise on the whole subject of Coal from the geological, chemical, mechanical, and industrial points of view, concluding with a chapter on the important topic known as the 'Coal Question.'*"—Daily News.

Cooke (Josiah P., Jun.).—FIRST PRINCIPLES OF CHEMICAL PHILOSOPHY. By JOSIAH P. COOKE, Jun., Ervine Professor of Chemistry and Mineralogy in Harvard College. Third Edition, revised and corrected. Crown 8vo. 12*s.*

Cooke (M. C.).—HANDBOOK OF BRITISH FUNGI, with full descriptions of all the Species, and Illustrations of the Genera. By M. C. COOKE, M.A. Two vols. crown 8vo. 24*s.*

"*Will maintain its place as the standard English book, on the subject of which it treats, for many years to come.*"—Standard.

Crossley.—HANDBOOK OF DOUBLE STARS, WITH A CATALOGUE OF 1,200 DOUBLE STARS AND EXTENSIVE LISTS OF MEASURES FOR THE USE OF AMATEURS. By E. CROSSLEY, F.R.A.S., J. GLEDHILL, F.R.A.S., and J. M. WILSON, F.R.A.S. With Illustrations. 8vo. 21*s.*

Dawkins.—Works by W. BOYD DAWKINS, F.R.S., &c., Professor of Geology at Owens College, Manchester.

CAVE-HUNTING: Researches on the Evidence of Caves respecting the Early Inhabitants of Europe. With Coloured Plate and Woodcuts. 8vo. 21*s.*

"*The mass of information he has brought together, with the judicious use he has made of his materials, will be found to invest his book with much of new and singular value.*"—Saturday Review.

EARLY MAN IN BRITAIN, AND HIS PLACE IN THE TERTIARY PERIOD. With Illustrations. 8vo. [*Shortly.*

Dawson (J. W.).—ACADIAN GEOLOGY. The Geologic Structure, Organic Remains, and Mineral Resources of Nova Scotia, New Brunswick, and Prince Edward Island. By JOHN WILLIAM DAWSON, M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of M'Gill College and University, Montreal, &c. With a Geological Map and numerous Illustrations. Third Edition, with Supplement. 8vo. 21*s.* Supplement, separately, 2*s.* 6*d.*

Fiske.—DARWINISM; AND OTHER ESSAYS. By JOHN FISKE, M.A., LL.D., formerly Lecturer on Philosophy in Harvard University. Crown 8vo. 7*s.* 6*d.*

Fleischer.—A SYSTEM OF VOLUMETRIC ANALYSIS. By Dr. E. FLEISCHER. Translated from the Second German Edition by M. M. Pattison Muir, with Notes and Additions. Illustrated. Crown 8vo. *7s. 6d.*

Flückiger and Hanbury.—PHARMACOGRAPHIA. A History of the Principal Drugs of Vegetble Origin met with in Great Britain and India. By F. A. FLÜCKIGER, M.D., and D. HANBURY, F.R.S. Second Edition, revised. 8vo. *21s.*

Forbes.—THE TRANSIT OF VENUS. By GEORGE FORBES, B.A., Professor of Natural Philosophy in the Andersonian University of Glasgow. With numerous Illustrations. Crown 8vo. *3s. 6d.*

Foster and Balfour.—ELEMENTS OF EMBRYOLOGY By MICHAEL FOSTER, M.D., F.R.S., and F. M. BALFOUR, M.A., Fellow of Trinity College, Cambridge. With numerous Illustrations. Part I. Crown 8vo. *7s. 6d.*

Galton.—Works by FRANCIS GALTON, F.R.S. :—

METEOROGRAPHICA, or Methods of Mapping the Weather. Illustrated by upwards of 600 Printed Lithographic Diagrams. 4to. *9s.*

HEREDITARY GENIUS: An Inquiry into its Laws and Consequences. Demy 8vo. *12s.*

The Times *calls it "a most able and most interesting book."*

ENGLISH MEN OF SCIENCE; THEIR NATURE AND NURTURE. 8vo. *8s. 6d.*

"*The book is certainly one of very great interest.*"—Nature.

Gamgee.—A TEXT-BOOK, SYSTEMATIC and PRACTICAL, OF THE PHYSIOLOGICAL CHEMISTRY OF THE ANIMAL BODY. By ARTHUR GAMGEE, M.D., F.R.S., Professor of Physiology in Owens College, Manchester. With Illustrations. 8vo. [*In the press.*

Geikie.—Works by ARCHIBALD GEIKIE, LL.D., F.R.S., Murchison Professor of Geology and Mineralogy at Edinburgh :—

ELEMENTARY LESSONS IN PHYSICAL GEOGRAPHY. With numerous Illustrations. Fcap. 8vo. *4s. 6d.* Questions, *1s. 6d.*

OUTLINES OF FIELD GEOLOGY. With Illustrations. Crown 8vo. *3s. 6d.*

PRIMER OF GEOLOGY. Illustrated. 18mo. *1s.*

PRIMER OF PHYSICAL GEOGRAPHY. Illustrated. 18mo. *1s.*

Gordon.—AN ELEMENTARY BOOK ON HEAT. By J. E. H. GORDON, B.A., Gonville and Caius College, Cambridge. Crown 8vo. *2s.*

Gray.—STRUCTURAL BOTANY ON THE BASIS OF MORPHOLOGY. By Professor ASA GRAY. With Illustrations. 8vo. [*In the press.*

Guillemin.—THE FORCES OF NATURE: A Popular Introduction to the Study of Physical Phenomena. By AMÉDÉE GUILLEMIN. Translated from the French by MRS. NORMAN LOCKYER; and Edited, with Additions and Notes, by J. NORMAN LOCKYER, F.R.S. Illustrated by Coloured Plates, and 455 Woodcuts. Third and cheaper Edition. Royal 8vo. 21*s.*

"*Translator and Editor have done justice to their task. The text has all the force and flow of original writing, combining faithfulness to the author's meaning with purity and independence in regard to idiom; while the historical precision and accuracy pervading the work throughout, speak of the watchful editorial supervision which has been given to every scientific detail. Nothing can well exceed the clearness and delicacy of the illustrative woodcuts. Altogether, the work may be said to have no parallel, either in point of fulness or attraction, as a popular manual of physical science.*"—Saturday Review.

THE APPLICATIONS OF PHYSICAL FORCES. By A. GUILLEMIN. Translated from the French by Mrs. LOCKYER, and Edited with Notes and Additions by J. N. LOCKYER, F.R.S. With Coloured Plates and numerous Illustrations. Cheaper Edition. Imperial 8vo. cloth, extra gilt. 36*s.*

Also in Eighteen Monthly Parts, price 1*s.* each. Part I. in November, 1878.

"*A book which we can heartily recommend, both on account of the width and soundness of its contents, and also because of the excellence of its print, its illustrations, and external appearance.*"—Westminster Review.

Hanbury.—SCIENCE PAPERS: chiefly Pharmacological and Botanical. By DANIEL HANBURY, F.R.S. Edited, with Memoir, by J. INCE, F.L.S., and Portrait engraved by C. H. JEENS. 8vo. 14*s.*

Henslow.—THE THEORY OF EVOLUTION OF LIVING THINGS, and Application of the Principles of Evolution to Religion considered as Illustrative of the Wisdom and Beneficence of the Almighty. By the Rev. GEORGE HENSLOW, M.A., F.L.S. Crown 8vo. 6*s.*

Hooker.—Works by Sir J. D. HOOKER, K.C.S.I., C.B., F.R.S., M.D., D.C.L.:—

THE STUDENT'S FLORA OF THE BRITISH ISLANDS. Second Edition, revised and improved. Globe 8vo. 10*s.* 6*d.*

"*Certainly the fullest and most accurate manual of the kind that has yet appeared. Dr. Hooker has shown his characteristic industry*

Hooker—*continued.*

and ability in the care and skill which he has thrown into the characters of the plants. These are to a great extent original, and are really admirable for their combination of clearness, brevity, and completeness."—Pall Mall Gazette.

PRIMER OF BOTANY. With Illustrations. 18mo. 1*s.* New Edition, revised and corrected.

Hooker and Ball.—JOURNAL OF A TOUR IN MAROCCO AND THE GREAT ATLAS. By Sir J. D. HOOKER, K.C.S.I., C.B., F.R.S., &c., and JOHN BALL, F.R.S. With Appendices, including a Sketch of the Geology of Marocco. By G. MAW, F.L.S., F.G.S. With Map and Illustrations. 8vo. 21*s.*

"*This is, without doubt, one of the most interesting and valuable books of travel published for many years."*—Spectator.

Huxley and Martin.—A COURSE OF PRACTICAL INSTRUCTION IN ELEMENTARY BIOLOGY. By T. H. HUXLEY, LL.D., Sec. R.S., assisted by H. N. MARTIN, B.A., M.B., D.Sc., Fellow of Christ's College, Cambridge. Crown 8vo. 6*s.*

"*This is the most thoroughly valuable book to teachers and students of biology which has ever appeared in the English tongue."*—London Quarterly Review.

Huxley (Professor).—LAY SERMONS, ADDRESSES, AND REVIEWS. By T. H. HUXLEY, LL.D., F.R.S. New and Cheaper Edition. Crown 8vo. 7*s.* 6*d.*

Fourteen Discourses on the following subjects:—(1) *On the Advisableness of Improving Natural Knowledge:*—(2) *Emancipation—Black and White:*—(3) *A Liberal Education, and where to find it:*—(4) *Scientific Education:*—(5) *On the Educational Value of the Natural History Sciences:*—(6) *On the Study of Zoology:*—(7) *On the Physical Basis of Life:*—(8) *The Scientific Aspects of Positivism:*—(9) *On a Piece of Chalk:*—(10) *Geological Contemporaneity and Persistent Types of Life:*—(11) *Geological Reform:*—(12) *The Origin of Species:*—(13) *Criticisms on the "Origin of Species:"*—(14) *On Descartes' "Discourse touching the Method of using One's Reason rightly and of seeking Scientific Truth."*

ESSAYS SELECTED FROM "LAY SERMONS, ADDRESSES, AND REVIEWS." Second Edition. Crown 8vo. 1*s.*

CRITIQUES AND ADDRESSES. 8vo. 10*s.* 6*d.*

Contents:—1. *Administrative Nihilism.* 2. *The School Boards: what they can do, and what they may do.* 3. *On Medical Education.* 4. *Yeast.* 5. *On the Formation of Coal.* 6. *On Coral and Coral Reefs.* 7. *On the Methods and Results of Ethnology.* 8. *On some Fixed Points in British Ethnology.* 9. *Palæontology*

Huxley (Professor)—*continued.*

and the Doctrine of Evolution. 10. *Biogenesis and Abiogenesis.* 11. *Mr. Darwin's Critics.* 12. *The Genealogy of Animals.* 13. *Bishop Berkeley on the Metaphysics of Sensation.*

LESSONS IN ELEMENTARY PHYSIOLOGY. With numerous Illustrations. New Edition. Fcap. 8vo. 4*s.* 6*d.*

"*Pure gold throughout.*"—Guardian. "*Unquestionably the clearest and most complete elementary treatise on this subject that we possess in any language.*"—Westminster Review.

AMERICAN ADDRESSES: with a Lecture on the Study of Biology. 8vo. 6*s.* 6*d.*

PHYSIOGRAPHY: An Introduction to the Study of Nature. With Coloured Plates and numerous Woodcuts. New Edition. Crown 8vo. 7*s.* 6*d.*

"*It would be hardly possible to place a more useful or suggestive book in the hands of learners and teachers, or one that is better calculated to make physiography a favourite subject in the science schools.*"—Academy.

Jellet (John H., B.D.).—A TREATISE ON THE THEORY OF FRICTION. By JOHN H. JELLET, B.D., Senior Fellow of Trinity College, Dublin; President of the Royal Irish Academy. 8vo. 8*s.* 6*d.*

Jones.—Works by FRANCIS JONES, F.R.S.E., F.C.S., Chemical Master in the Grammar School, Manchester.

THE OWENS COLLEGE JUNIOR COURSE OF PRACTICAL CHEMISTRY. With Preface by Professor ROSCOE. New Edition. 18mo. With Illustrations. 2*s.* 6*d.*

QUESTIONS ON CHEMISTRY. A Series of Problems and Exercises in Inorganic and Organic Chemistry. 18mo. 3*s.*

Kingsley.—GLAUCUS: OR, THE WONDERS OF THE SHORE. By CHARLES KINGSLEY, Canon of Westminster. New Edition, with numerous Coloured Plates. Crown 8vo. 6*s.*

Landauer.—BLOWPIPE ANALYSIS. By J. LANDAUER. Authorised English Edition, by JAMES TAYLOR and W. E. KAY, of the Owens College, Manchester. With Illustrations. Extra fcap. 8vo. 4*s* 6*d.*

Langdon.—THE APPLICATION OF ELECTRICITY TO RAILWAY WORKING. By W. E. LANGDON, Member of the Society of Telegraph Engineers. With numerous Illustrations. Extra fcap. 8vo. 4*s.* 6*d.*

"*There is no officer in the telegraph service who will not profit by the study of this book.*"—Mining Journal.

Lockyer (J. N.).—Works by J. NORMAN LOCKYER, F.R.S.—
ELEMENTARY LESSONS IN ASTRONOMY. With numerous Illustrations. New Edition. Fcap. 8vo. 5*s.* 6*d.*

"*The book is full, clear, sound, and worthy of attention, not only as a popular exposition, but as a scientific 'Index.'*"—Athenæum.

THE SPECTROSCOPE AND ITS APPLICATIONS. By J. NORMAN LOCKYER, F.R.S. With Coloured Plate and numerous Illustrations. Second Edition. Crown 8vo. 3*s.* 6*d.*

CONTRIBUTIONS TO SOLAR PHYSICS. By J. NORMAN LOCKYER, F.R.S. I. A Popular Account of Inquiries into the Physical Constitution of the Sun, with especial reference to Recent Spectroscopic Researches. II. Communications to the Royal Society of London and the French Academy of Sciences, with Notes. Illustrated by 7 Coloured Lithographic Plates and 175 Woodcuts. Royal 8vo. cloth, extra gilt, price 31*s.* 6*d.*

"*The book may be taken as an authentic exposition of the present state of science in connection with the important subject of spectroscopic analysis. . . . Even the unscientific public may derive much information from it.*"—Daily News.

PRIMER OF ASTRONOMY. With Illustrations. 18mo. 1*s.*

Lockyer and Seabroke.—STAR-GAZING: PAST AND PRESENT. An Introduction to Instrumental Astronomy. By J. N. LOCKYER, F.R.S. Expanded from Shorthand Notes of a Course of Royal Institution Lectures with the assistance of G. M. SEABROKE, F.R.A.S. With numerous Illustrations. Royal 8vo. 21*s.*

"*A book of great interest and utility to the astronomical student.*" —Athenæum.

Lubbock.—Works by SIR JOHN LUBBOCK, M.P., F.R.S., D.C.L.:
THE ORIGIN AND METAMORPHOSES OF INSECTS. With Numerous Illustrations. Second Edition. Crown 8vo. 3*s.* 6*d.*

"*As a summary of the phenomena of insect metamorphoses his little book is of great value, and will be read with interest and profit by all students of natural history. The whole chapter on the origin of insects is most interesting and valuable. The illustrations are numerous and good.*"—Westminster Review.

ON BRITISH WILD FLOWERS CONSIDERED IN RELATION TO INSECTS. With Numerous Illustrations. Second Edition. Crown 8vo. 4*s.* 6*d.*

SCIENTIFIC LECTURES. With Illustrations. 8vo. 8*s.* 6*d.*

CONTENTS:—*Flowers and Insects—Plants and Insects—The Habits of Ants—Introduction to the Study of Prehistoric Archæology, &c.*

Macmillan (Rev. Hugh).—For other Works by the same Author, see THEOLOGICAL CATALOGUE.
HOLIDAYS ON HIGH LANDS; or, Rambles and Incidents in search of Alpine Plants. Globe 8vo. cloth. 6*s.*

Oliver—*continued.*

LESSONS IN ELEMENTARY BOTANY. With nearly Two Hundred Illustrations. New Edition. Fcap. 8vo. 4*s.* 6*d.*

FIRST BOOK OF INDIAN BOTANY. With numerous Illustrations. Extra fcap. 8vo. 6*s.* 6*d.*

"*It contains a well-digested summary of all essential knowledge pertaining to Indian Botany, wrought out in accordance with the best principles of scientific arrangement.*"—Allen's Indian Mail.

Pasteur.—STUDIES ON FERMENTATION. The Diseases of Beer; their Causes and Means of Preventing them. By L. PASTEUR. A Translation of "Études sur la Bière," With Notes, Illustrations, &c. By F. FAULKNER and D. C. ROBB, B.A. 8vo. 21*s.*

Pennington.—NOTES ON THE BARROWS AND BONE CAVES OF DERBYSHIRE. With an account of a Descent into Elden Hole. By ROOKE PENNINGTON, B.A., LL.B., F.G.S. 8vo. 6*s.*

Penrose (F. C.)—ON A METHOD OF PREDICTING BY GRAPHICAL CONSTRUCTION, OCCULTATIONS OF STARS BY THE MOON, AND SOLAR ECLIPSES FOR ANY GIVEN PLACE. Together with more rigorous methods for the Accurate Calculation of Longitude. By F. C. PENROSE, F.R.A.S. With Charts, Tables, &c. 4to. 12*s.*

Perry.—AN ELEMENTARY TREATISE ON STEAM. By JOHN PERRY, B.E., Professor of Engineering, Imperial College of Engineering, Yedo. With numerous Woodcuts, Numerical Examples, and Exercises. 18mo. 4*s.* 6*d.*

"*Mr. Perry has in this compact little volume brought together an immense amount of information, new told, regarding steam and its application, not the least of its merits being that it is suited to the capacities alike of the tyro in engineering science or the better grade of artisan.*"—Iron.

Pickering.—ELEMENTS OF PHYSICAL MANIPULATION. By E. C. PICKERING, Thayer Professor of Physics in the Massachusetts Institute of Technology. Part I., medium 8vo. 10*s.* 6*d.* Part II., 10*s.* 6*d.*

"*When finished 'Physical Manipulation' will no doubt be considered the best and most complete text-book on the subject of which it treats.*"—Nature.

Prestwich.—THE PAST AND FUTURE OF GEOLOGY. An Inaugural Lecture, by J. PRESTWICH, M.A., F.R.S., &c., Professor of Geology, Oxford. 8vo. 2*s.*

Radcliffe.—PROTEUS: OR UNITY IN NATURE. By. C. B. RADCLIFFE, M.D., Author of "Vital Motion as a mode of Physical Motion. Second Edition. 8vo. 7*s.* 6*d.*

Rendu.—THE THEORY OF THE GLACIERS OF SAVOY. By M. LE CHANOINE RENDU. Translated by A. WELLS, Q.C., late President of the Alpine Club. To which are added, the Original Memoir and Supplementary Articles by Professors TAIT and RUSKIN. Edited with Introductory remarks by GEORGE FORBES, B.A., Professor of Natural Philosophy in the Andersonian University, Glasgow. 8vo. 7*s.* 6*d.*

Roscoe.—Works by HENRY E. ROSCOE, F.R.S., Professor of Chemistry in Owens College, Manchester :—

LESSONS IN ELEMENTARY CHEMISTRY, INORGANIC AND ORGANIC. With numerous Illustrations and Chromo-litho of the Solar Spectrum, and of the Alkalis and Alkaline Earths. New Edition. Fcap. 8vo. 4*s.* 6*d.*

CHEMICAL PROBLEMS, adapted to the above by Professor THORPE. Fifth Edition, with Key. 2*s.*

"*We unhesitatingly pronounce it the best of all our elementary treatises on Chemistry.*"—Medical Times.

PRIMER OF CHEMISTRY. Illustrated. 18mo. 1*s.*

Roscoe and Schorlemmer.—A TREATISE ON INORGANIC CHEMISTRY. With numerous Illustrations. By PROFESSORS ROSCOE and SCHORLEMMER.

Vol. I., The Non-metallic Elements. 8vo. 21*s.*

Vol. II., Part I. Metals. 8vo. 18*s.*

Vol. II., Part II. Metals. 8vo. 18*s.*

"*Regarded as a treatise on the Non-metallic Elements, there can be no doubt that this volume is incomparably the most satisfactory one of which we are in possession.*"—Spectator.

"*It would be difficult to praise the work too highly. All the merits which we noticed in the first volume are conspicuous in the second. The arrangement is clear and scientific; the facts gained by modern research are fairly represented and judiciously selected; and the style throughout is singularly lucid.*"—Lancet.

Rumford (Count).—THE LIFE AND COMPLETE WORKS OF BENJAMIN THOMPSON, COUNT RUMFORD. With Notices of his Daughter. By GEORGE ELLIS. With Portrait. Five Vols. 8vo. 4*l.* 14*s.* 6*d.*

Schorlemmer.—A MANUAL OF THE CHEMISTRY OF THE CARBON COMPOUNDS OR ORGANIC CHEMISTRY. By C. SCHORLEMMER, F.R.S., Lecturer in Organic Chemistry in Owens College, Manchester. 8vo. 14*s.*

"*It appears to us to be as complete a manual of the metamorphoses of carbon as could be at present produced, and it must prove eminently useful to the chemical student.*"—Athenæum.

Shann.—AN ELEMENTARY TREATISE ON HEAT, IN RELATION TO STEAM AND THE STEAM ENGINE. By G. SHANN, M.A. With Illustrations. Crown 8vo. 4*s.* 6*d.*

Smith.—HISTORIA FILICUM: An Exposition of the Nature, Number, and Organography of Ferns, and Review of the Principles upon which Genera are founded, and the Systems of Classification of the principal Authors, with a new General Arrangement, &c. By J. SMITH. A.L.S., ex-Curator of the Royal Botanic Garden, Kew. With Thirty Lithographic Plates by W. H. FITCH, F.L.S. Crown 8vo. 12*s.* 6*d.*

"*No one anxious to work up a thorough knowledge of ferns can afford to do without it.*"—Gardener's Chronicle.

South Kensington Science Lectures.

Vol. I.—Containing Lectures by Captain ABNEY, F.RS., Professor STOKES, Professor KENNEDY, F. J. BRAMWELL, F.R.S., Professor G. FORBES, H. C. SORBY, F.R.S., J. T. BOTTOMLEY, F.R.S.E., S. H. VINES, B.Sc., and Professor CAREY FOSTER. Crown 8vo. 6*s.* [Vol. II. *nearly ready.*

Vol. II.—Containing Lectures by W. SPOTTISWOODE, P.R.S., Prof. FORBES, H. W. CHISHOLM, Prof. T. F. PIGOT, W. FROUDE, F.R.S., Dr. SIEMENS, Prof. BARRETT, Dr. BURDEN-SANDERSON, Dr. LAUDER BRUNTON, F.R.S., Prof. MCLEOD, Prof. ROSCOE, F.R.S., &c. Crown 8vo. 6*s.*

Spottiswoode.—POLARIZATION OF LIGHT. By W. SPOTTISWOODE, President of the Royal Society. With numerous Illustrations. Second Edition. Cr. 8vo. 3*s.* 6*d.* (Nature Series.)

"*The illustrations are exceedingly well adapted to assist in making the text comprehensible.*"—Athenæum. "*A clear, trustworthy manual.*"—Standard.

Stewart (B.).—Works by BALFOUR STEWART, F.R.S., Professor of Natural Philosophy in Owens College, Manchester:—

LESSONS IN ELEMENTARY PHYSICS. With numerous Illustrations and Chromolithos of the Spectra of the Sun, Stars, and Nebulæ. New Edition. Fcap. 8vo. 4*s.* 6*d.*

The Educational Times *calls this the beau-idéal of a scientific text-book, clear, accurate, and thorough.*"

PRIMER OF PHYSICS. With Illustrations. New Edition, with Questions. 18mo. 1*s.*

Stewart and Tait.—THE UNSEEN UNIVERSE: or, Physical Speculations on a Future State. By BALFOUR STEWART, F.R.S., and P. G. TAIT, M.A. Sixth Edition. Crown 8vo. 6*s.*

"*The book is one which well deserves the attention of thoughtful and religious readers. . . . It is a perfectly sober inquiry, on scientific grounds, into the possibilities of a future existence.*"—Guardian.

Stone.—ELEMENTARY LESSONS ON SOUND. By Dr. W. H. STONE, Lecturer on Physics at St. Thomas' Hospital. With Illustrations. Fcap. 8vo. 3*s*. 6*d*.

Tait.—LECTURES ON SOME RECENT ADVANCES IN PHYSICAL SCIENCE. By P. G. TAIT, M.A., Professor of Philosophy in the University of Edinburgh. Second edition, revised and enlarged, with the Lecture on Force delivered before the British Association. Crown 8vo. 9*s*.

Tanner.—FIRST PRINCIPLES OF AGRICULTURE. By HENRY TANNER, F.C.S., Professor of Agricultural Science, University College, Aberystwith, Examiner in the Principles of Agriculture under the Government Department of Science. 18mo. 1*s*.

Taylor.—SOUND AND MUSIC: A Non-Mathematical Treatise on the Physical Constitution of Musical Sounds and Harmony, including the Chief Acoustical Discoveries of Professor Helmholtz. By SEDLEY TAYLOR, M.A., late Fellow of Trinity Colledge, Cambridge. Large crown 8vo. 8*s*. 6*d*.

"*In no previous scientific treatise do we remember so exhaustive and so richly illustrated a description of forms of vibration and of wave-moti n in fluids.*"—Musical Standard.

Thomson.—Works by SIR WYVILLE THOMSON, K.C.B., F.R.S.

THE DEPTHS OF THE SEA: An Account of the General Results of the Dredging Cruises of H.M.SS. "Porcupine" and "Lightning" during the Summers of 1868-69 and 70, under the scientific direction of Dr. Carpenter, F.R.S., J. Gwyn Jeffreys, F.R.S., and Sir Wyville Thomson, F.R.S. With nearly 100 Illustrations and 8 coloured Maps and Plans. Second Edition. Royal 8vo. cloth, gilt. 31*s*. 6*d*.

The Athenæum *says*: "*The book is full of interesting matter, and is written by a master of the art of popular exposition. It is excellently illustrated, both coloured maps and woodcuts possessing high merit. Those who have already become interested in dredging operations will of course make a point of reading this work; those who wish to be pleasantly introduced to the subject, and rightly to appreciate the news which arrives from time to time from the 'Challenger,' should not fail to seek instruction from it.*"

THE VOYAGE OF THE "CHALLENGER."—THE ATLANTIC. A Preliminary account of the Exploring Voyages of H.M.S. "Challenger," during the year 1873 and the early part of 1876. With numerous Illustrations, Coloured Maps & Charts, & Portrait of the Author, engraved by C. H. JEENS. 2 Vols. Medium 8vo. 42*s*.

The Times *says*:—"*It is right that the public should have some authoritative account of the general results of the expedition, and*

Thomson—*continued.*

that as many of the ascertained data as may be accepted with confidence should speedily find their place in the general body of scientific knowledge. No one can be more competent than the accomplished scientific chief of the expedition to satisfy the public in this respect. . . . The paper, printing, and especially the numerous illustrations, are of the highest quality. . . . We have rarely, if ever, seen more beautiful specimens of wood engraving than abound in this work. . . . Sir Wyville Thomson's style is particularly attractive; he is easy and graceful, but vigorous and exceedingly happy in the choice of language, and throughout the work there are touches which show that science has not banished sentiment from his bosom."

Thudichum and Dupré.—A TREATISE ON THE ORIGIN, NATURE, AND VARIETIES OF WINE. Being a Complete Manual of Viticulture and Œnology. By J. L. W. THUDICHUM, M.D., and AUGUST DUPRÉ, Ph.D., Lecturer on Chemistry at Westminster Hospital. Medium 8vo. cloth gilt. 25*s.*

"*A treatise almost unique for its usefulness either to the wine-grower, the vendor, or the consumer of wine. The analyses of wine are the most complete we have yet seen, exhibiting at a glance the constituent principles of nearly all the wines known in this country.*" —Wine Trade Review.

Wallace (A. R.).—Works by ALFRED RUSSEL WALLACE.

CONTRIBUTIONS TO THE THEORY OF NATURAL SELECTION. A Series of Essays. New Edition, with Corrections and Additions. Crown 8vo. 8*s.* 6*d.*

The Saturday Review *says: "He has combined an abundance of fresh and original facts with a liveliness and sagacity of reasoning which are not often displayed so effectively on so small a scale."*

THE GEOGRAPHICAL DISTRIBUTION OF ANIMALS, with a study of the Relations of Living and Extinct Faunas as Elucidating the Past Changes of the Earth's Surface. 2 vols. 8vo. with Maps, and numerous Illustrations by Zwecker, 42*s.*

The Times *says: "Altogether it is a wonderful and fascinating story, whatever objections may be taken to theories founded upon it. Mr. Wallace has not attempted to add to its interest by any adornments of style; he has given a simple and clear statement of intrinsically interesting facts, and what he considers to be legitimate inductions from them. Naturalists ought to be grateful to him for having undertaken so toilsome a task. The work, indeed, is a credit to all concerned—the author, the publishers, the artist—unfortunately now no more—of the attractive illustrations—last but by no means least, Mr. Stanford's map-designer."*

Wallace (A. R.)—*continued.*

TROPICAL NATURE: with other Essays. 8vo. 12*s.*

"*Nowhere amid the many descriptions of the tropics that have been given is to be found a summary of the past history and actual phenomena of the tropics which gives that which is distinctive of the phases of nature in them more clearly, shortly, and impressively.*"—Saturday Review.

Warington.—THE WEEK OF CREATION; OR, THE COSMOGONY OF GENESIS CONSIDERED IN ITS RELATION TO MODERN SCIENCE. By GEORGE WARINGTON, Author of "The Historic Character of the Pentateuch Vindicated." Crown 8vo. 4*s.* 6*d.*

Wilson.—RELIGIO CHEMICI. By the late GEORGE WILSON, M.D., F.R.S.E., Regius Professor of Technology in the University of Edinburgh. With a Vignette beautifully engraved after a design by Sir NOEL PATON. Crown 8vo. 8*s.* 6*d.*

Wilson (Daniel).—CALIBAN: a Critique on Shakespeare's "Tempest" and "Midsummer Night's Dream." By DANIEL WILSON, LL.D., Professor of History and English Literature in University College, Toronto. 8vo. 10*s.* 6*d.*

"*The whole volume is most rich in the eloquence of thought and imagination as well as of words. It is a choice contribution at once to science, theology, religion, and literature.*"—British Quarterly Review.

Wright.—METALS AND THEIR CHIEF INDUSTRIAL APPLICATIONS. By C. ALDER WRIGHT, D.Sc., &c., Lecturer on Chemistry in St. Mary's Hospital School. Extra fcap. 8vo. 3*s.* 6*d.*

Wurtz.—A HISTORY OF CHEMICAL THEORY, from the Age of Lavoisier down to the present time. By AD. WURTZ. Translated by HENRY WATTS, F.R.S. Crown 8vo. 6*s.*

"*The discourse, as a* résumé *of chemical theory and research, unites singular luminousness and grasp. A few judicious notes are added by the translator.*"—Pall Mall Gazette. "*The treatment of the subject is admirable, and the translator has evidently done his duty most efficiently.*"—Westminster Review.

Elementary Science Class-books—*continued.*

Physics.—LESSONS IN ELEMENTARY PHYSICS. By BALFOUR STEWART, F.R.S., Professor of Natural Philosophy in Owens College, Manchester. With numerous Illustrations and Chromo-Litho of the Spectra of the Sun, Stars, and Nebulæ. New Edition. Fcap. 8vo. 4*s.* 6*d.*

Anatomy.—LESSONS IN ELEMENTARY ANATOMY. By ST. GEORGE MIVART, F.R.S., Lecturer in Comparative Anatomy at St. Mary's Hospital. With upwards of 400 Illustrations. Fcap. 8vo. 6*s.* 6*d.*

Mechanics.—AN ELEMENTARY TREATISE. By A. B. W. KENNEDY, C.E., Professor of Applied Mechanics in University College, London. With Illustrations. [*In preparation.*

Steam.—AN ELEMENTARY TREATISE. By JOHN PERRY, Professor of Engineering, Imperial College of Engineering, Yedo. With numerous Woodcuts and Numerical Examples and Exercises. 18mo. 4*s.* 6*d.*

Physical Geography. — ELEMENTARY LESSONS IN PHYSICAL GEOGRAPHY. By A. GEIKIE, F.R.S., Murchison Professor of Geology, &c., Edinburgh. With numerous Illustrations. Fcap. 8vo. 4*s.* 6*d.*

QUESTIONS ON THE SAME. 1*s.* 6*d.*

Geography.—CLASS-BOOK OF GEOGRAPHY. By C. B. CLARKE, M.A., F.R.G.S. Fcap. 8vo. 2*s.* 6*d.*

Natural Philosophy.—NATURAL PHILOSOPHY FOR BEGINNERS. By I. TODHUNTER, M.A., F.R.S. Part I. The Properties of Solid and Fluid Bodies. 18mo. 3*s.* 6*d.* Part II. Sound, Light, and Heat. 18mo. 3*s.* 6*d.*

Sound.—AN ELEMENTARY TREATISE. By Dr. W. H. STONE. With Illustrations. 18mo. 3*s.* 6*d.*

Others in Preparation.

MANUALS FOR STUDENTS.

Crown 8vo.

Dyer and Vines.—THE STRUCTURE OF PLANTS. By Professor THISELTON DYER, F.R.S., assisted by SYDNEY VINES, B.Sc., Fellow and Lecturer of Christ's College, Cambridge. With numerous Illustrations. [*In preparation.*

Manuals for Students—*continued.*

Fawcett.—A MANUAL OF POLITICAL ECONOMY. By Professor FAWCETT, M.P. New Edition, revised and enlarged. Crown 8vo. 12*s*. 6*d*.

Fleischer.—A SYSTEM OF VOLUMETRIC ANALYSIS. Translated, with Notes and Additions, from the second German Edition, by M. M. PATTISON MUIR, F.R.S.E. With Illustrations. Crown 8vo. 7*s*. 6*d*.

Flower (W. H.).—AN INTRODUCTION TO THE OSTEOLOGY OF THE MAMMALIA. Being the Substance of the Course of Lectures delivered at the Royal College of Surgeons of England in 1870. By Professor W. H. FLOWER, F.R.S., F.R.C.S. With numerous Illustrations. New Edition, enlarged. Crown 8vo. 10*s*. 6*d*.

Foster and Balfour.—THE ELEMENTS OF EMBRYOLOGY. By MICHAEL FOSTER, M.D., F.R.S., and F. M. BALFOUR, M.A. Part I. crown 8vo. 7*s*. 6*d*.

Foster and Langley.—A COURSE OF ELEMENTARY PRACTICAL PHYSIOLOGY. By MICHAEL FOSTER, M.D., F.R.S., and J. N. LANGLEY, B.A. New Edition. Crown 8vo. 6*s*.

Hooker (Dr.)—THE STUDENT'S FLORA OF THE BRITISH ISLANDS. By Sir J. D. HOOKER, K.C.S.I., C.B., F.R.S., M.D., D.C.L. New Edition, revised. Globe 8vo. 10*s*. 6*d*.

Huxley.—PHYSIOGRAPHY. An Introduction to the Study of Nature. By Professor HUXLEY, F.R.S. With numerous Illustrations, and Coloured Plates. New Edition. Crown 8vo. 7*s*. 6*d*.

Huxley and Martin.—A COURSE OF PRACTICAL INSTRUCTION IN ELEMENTARY BIOLOGY. By Professor HUXLEY, F.R.S., assisted by H. N. MARTIN, M.B., D.Sc. New Edition, revised. Crown 8vo. 6*s*.

Huxley and Parker.—ELEMENTARY BIOLOGY. PART II. By Professor HUXLEY, F.R.S., assisted by — PARKER. With Illustrations. [*In preparation.*

Jevons.—THE PRINCIPLES OF SCIENCE. A Treatise on Logic and Scientific Method. By Professor W. STANLEY JEVONS, LL.D., F.R.S., New and Revised Edition. Crown 8vo. 12*s*. 6*d*.

Manuals for Students—*continued.*

Oliver (Professor).—FIRST BOOK OF INDIAN BOTANY. By Professor DANIEL OLIVER, F.R.S., F.L.S., Keeper of the Herbarium and Library of the Royal Gardens, Kew. With numerous Illustrations. Extra fcap. 8vo. 6*s.* 6*d.*

Parker and Bettany.—THE MORPHOLOGY OF THE SKULL. By Professor PARKER and G. T. BETTANY. Illustrated. Crown 8vo. 10*s.* 6*d.*

Tait.—AN ELEMENTARY TREATISE ON HEAT. By Professor TAIT, F.R.S.E. Illustrated. [*In the Press.*

Thomson.—ZOOLOGY. By Sir C. WYVILLE THOMSON, F.R.S. Illustrated. [*In preparation.*

Tylor and Lankester.—ANTHROPOLOGY. By E. B. TYLOR, M.A., F.R.S., and Professor E. RAY LANKESTER, M.A., F.R.S. Illustrated. [*In preparation.*

Other volumes of these Manuals will follow.

WORKS ON MENTAL AND MORAL PHILOSOPHY, AND ALLIED SUBJECTS.

Aristotle.—AN INTRODUCTION TO ARISTOTLE'S RHETORIC. With Analysis, Notes, and Appendices. By E. M. COPE, Trinity College, Cambridge. 8vo. 14*s.*

ARISTOTLE ON FALLACIES; OR, THE SOPHISTICI ELENCHI. With a Translation and Notes by EDWARD POSTE, M.A., Fellow of Oriel College, Oxford. 8vo. 8*s.* 6*d.*

Balfour.—A DEFENCE OF PHILOSOPHIC DOUBT: being an Essay on the Foundations of Belief. By A. J. BALFOUR, M.P. 8vo. 12*s.*

"*Mr. Balfour's criticism is exceedingly brilliant and suggestive.*"—Pall Mall Gazette.

"*An able and refreshing contribution to one of the burning questions of the age, and deserves to make its mark in the fierce battle now raging between science and theology.*"—Athenæum.

Birks.—Works by the Rev. T. R. BIRKS, Professor of Moral Philosophy, Cambridge:—

FIRST PRINCIPLES OF MORAL SCIENCE; or, a First Course of Lectures delivered in the University of Cambridge. Crown 8vo. 8*s.* 6*d.*

This work treats of three topics all preliminary to the direct exposition of Moral Philosophy. These are the Certainty and Dignity of Moral Science, its Spiritual Geography, or relation to other main subjects of human thought, and its Formative Principles, or some elementary truths on which its whole development must depend.

MODERN UTILITARIANISM; or, The Systems of Paley, Bentham, and Mill, Examined and Compared. Crown 8vo. 6*s.* 6*d.*

MODERN PHYSICAL FATALISM, AND THE DOCTRINE OF EVOLUTION; including an Examination of Herbert Spencer's First Principles. Crown 8vo. 6*s.*

SUPERNATURAL REVELATION; or, First Principles of Moral Theology. 8vo. 8*s.*

Boole.—AN INVESTIGATION OF THE LAWS OF THOUGHT, ON WHICH ARE FOUNDED THE MATHEMATICAL THEORIES OF LOGIC AND PROBABILITIES. By GEORGE BOOLE, LL.D., Professor of Mathematics in the Queen's University, Ireland, &c. 8vo. 14*s.*

Butler.—LECTURES ON THE HISTORY OF ANCIENT PHILOSOPHY. By W. ARCHER BUTLER, late Professor of Moral Philosophy in the University of Dublin. Edited from the Author's MSS., with Notes, by WILLIAM HEPWORTH THOMPSON, M.A., Master of Trinity College, and Regius Professor of Greek in the University of Cambridge. New and Cheaper Edition, revised by the Editor. 8vo. 12*s.*

Caird.—A CRITICAL ACCOUNT OF THE PHILOSOPHY OF KANT. With an Historical Introduction. By E. CAIRD, M.A., Professor of Moral Philosophy in the University of Glasgow. 8vo. 18*s.*

Calderwood.—Works by the Rev. HENRY CALDERWOOD, M.A., LL.D., Professor of Moral Philosophy in the University of Edinburgh :—

PHILOSOPHY OF THE INFINITE: A Treatise on Man's Knowledge of the Infinite Being, in answer to Sir W. Hamilton and Dr. Mansel. Cheaper Edition. 8vo. 7*s.* 6*d.*

"*A book of great ability . . . . written in a clear stle, and may be easily understood by even those who are not versed in such discussions.*"—British Quarterly Review.

A HANDBOOK OF MORAL PHILOSOPHY. Sixth Edition. Crown 8vo. 6*s.*

"*It is, we feel convinced, the best handbook on the subject, intellectually and morally, and does infinite credit to its author.*"—Standard. "*A compact and useful work, going over a great deal of ground in a manner adapted to suggest and facilitate further study. . . . His book will be an assistance to many students outside his own University of Edinburgh.* —Guardian.

THE RELATIONS OF MIND AND BRAIN. 8vo. 12*s.*

"*It should be of real service as a clear exposition and a searching criticism of cerebral pyschology.*"—Westminster Review.

"*Altogether his work is probably the best combination to be found at present in England of exposition and criticism on the subject of physiological psychology.*"—The Academy.

Clifford.—LECTURES AND ESSAYS. By the late Professor W. K. CLIFFORD, F.R.S. Edited by LESLIE STEPHEN and FREDERICK POLLOCK, with Introduction by F. POLLOCK. Two Portraits. 2 vols. 8vo. 25*s.*

Clifford—*continued.*

"*The* Times *of October 22nd says:—"Many a friend of the author on first taking up these volumes and remembering his versatile genius and his keen enjoyment of all realms of intellectual activity must have trembled, lest they should be found to consist of fragmentary pieces of work, too disconnected to do justice to his powers of consecutive reading, and too varied to have any effect as a whole. Fortunately these fears are groundless. . . . It is not only in subject that the various papers are closely related. There is also a singular consistency of view and of method throughout. . . . It is in the social and metaphysical subjects that the richness of his intellect shows itself, most forcibly in the rarity and originality of the ideas which he presents to us. To appreciate this variety it is necessary to read the book itself, for it treats in some form or other of all the subjects of deepest interest in this age of questioning.*"

Fiske.—OUTLINES OF COSMIC PHILOSOPHY, BASED ON THE DOCTRINE OF EVOLUTION, WITH CRITICISMS ON THE POSITIVE PHILOSOPHY. By JOHN FISKE, M.A., LL.B., formerly Lecturer on Philosophy at Harvard University. 2 vols. 8vo. 25*s.*

"*The work constitutes a very effective encyclopædia of the evolutionary philosophy, and is well worth the study of all who wish to see at once the entire scope and purport of the scientific dogmatism of the day.*"—Saturday Review.

Harper.—THE METAPHYSICS OF THE SCHOOL. By the Rev. THOMAS HARPER (S.J.). In 5 vols. 8vo.

[*Vol I. in November.*

Herbert.—THE REALISTIC ASSUMPTIONS OF MODERN SCIENCE EXAMINED. By T. M. HERBERT, M.A., late Professor of Philosophy, &c., in the Lancashire Independent College, Manchester. 8vo. 14*s.*

"*Mr. Herbert's work appears to us one of real ability and importance. The author has shown himself well trained in philosophical literature, and possessed of high critical and speculative powers.*"—Mind.

Jardine.—THE ELEMENTS OF THE PSYCHOLOGY OF COGNITION. By ROBERT JARDINE, B.D., D.Sc., Principal of the General Assembly's College, Calcutta, and Fellow of the University of Calcutta. Crown 8vo. 6*s.* 6*d.*

Jevons.—Works by W. STANLEY JEVONS, LL.D., M.A., F.R.S., Professor of Political Economy, University College, London.

Jevons—*continued.*

THE PRINCIPLES OF SCIENCE. A Treatise on Logic and Scientific Method. New and Cheaper Edition, revised. Crown 8vo. 12*s.* 6*d.*

"*No one in future can be said to have any true knowledge of what has been done in the way of logical and scientific method in England without having carefully studied Professor Jevons' book.*"—Spectator.

THE SUBSTITUTION OF SIMILARS, the True Principle of Reasoning. Derived from a Modification of Aristotle's Dictum. Fcap. 8vo. 2*s.* 6*d.*

ELEMENTARY LESSONS IN LOGIC, DEDUCTIVE AND INDUCTIVE. With Questions, Examples, and Vocabulary of Logical Terms. New Edition. Fcap. 8vo. 3*s.* 6*d.*

PRIMER OF LOGIC. New Edition. 18mo. 1*s.*

Maccoll.—THE GREEK SCEPTICS, from Pyrrho to Sextus. An Essay which obtained the Hare Prize in the year 1868. By NORMAN MACCOLL, B.A., Scholar of Downing College, Cambridge. Crown 8vo. 3*s.* 6*d.*

M'Cosh.—Works by JAMES M'COSH, LL.D., President of Princeton College, New Jersey, U.S.

"*He certainly shows himself skilful in that application of logic to psychology, in that inductive science of the human mind which is the fine side of English philosophy. His philosophy as a whole is worthy of attention.*"—Revue de Deux Mondes.

THE METHOD OF THE DIVINE GOVERNMENT, Physical and Moral. Tenth Edition. 8vo. 10*s.* 6*d.*

"*This work is distinguished from other similar ones by its being based upon a thorough study of physical science, and an accurate knowledge of its present condition, and by its entering in a deeper and more unfettered manner than its predecessors upon the discussion of the appropriate psychological, ethical, and theological questions. The author keeps aloof at once from the* à priori *idealism and dreaminess of German speculation since Schelling, and from the onesidedness and narrowness of the empiricism and positivism which have so prevailed in England.*"—Dr. Ulrici, in "Zeitschrift für Philosophie."

THE INTUITIONS OF THE MIND. A New Edition. 8vo. cloth. 10*s.* 6*d.*

"*The undertaking to adjust the claims of the sensational and intuitional philosophies, and of the* à posteriori *and* à priori *methods, is accomplished in this work with a great amount of success.*"—Westminster Review. "*I value it for its large acquaintance with English Philosophy, which has not led him to neglect the great German works. I admire the moderation and clearness, as well as comprehensiveness, of the author's views.*"—Dr. Dörner, of Berlin.

M'Cosh—*continued.*

AN EXAMINATION OF MR. J. S. MILL'S PHILOSOPHY: Being a Defence of Fundamental Truth. Second edition, with additions. 10*s.* 6*d.*

"*Such a work greatly needed to be done, and the author was the man to do it. This volume is important, not merely in reference to the views of Mr. Mill, but of the whole school of writers, past and present, British and Continental, he so ably represents.*"—Princeton Review.

THE LAWS OF DISCURSIVE THOUGHT: Being a Text-book of Formal Logic. Crown 8vo. 5*s.*

"*The amount of summarized information which it contains is very great; and it is the only work on the very important subject with which it deals. Never was such a work so much needed as in the present day.*"—London Quarterly Review.

CHRISTIANITY AND POSITIVISM: A Series of Lectures to the Times on Natural Theology and Apologetics. Crown 8vo. 7*s.* 6*d.*

THE SCOTTISH PHILOSOPHY FROM HUTCHESON TO HAMILTON, Biographical, Critical, Expository. Royal 8vo. 16*s.*

Masson.—RECENT BRITISH PHILOSOPHY: A Review with Criticisms; including some Comments on Mr. Mill's Answer to Sir William Hamilton. By DAVID MASSON, M.A., Professor of Rhetoric and English Literature in the University of Edinburgh. Third Edition, with an Additional Chapter. Crown 8vo. 6*s*

"*We can nowhere point to a work which gives so clear an exposition of the course of philosophical speculation in Britain during the past century, or which indicates so instructively the mutual influences of philosophic and scientific thought.*"—Fortnightly Review.

Maudsley.—Works by H. MAUDSLEY, M.D., Professor of Medical Jurisprudence in University College, London.

THE PHYSIOLOGY OF MIND; being the First Part of a Third Edition, Revised, Enlarged, and in great part Re-written, of "The Physiology and Pathology of Mind." Crown 8vo. 10*s.* 6*d.*

THE PATHOLOGY OF MIND. Revised, Enlarged, and in great part Re-written. 8vo. 18*s.*

BODY AND MIND: an Inquiry into their Connexion and Mutual Influence, specially with reference to Mental Disorders. An Enlarged and Revised edition. To which are added, Psychological Essays. Crown 8vo. 6*s.* 6*d.*

Maurice.—Works by the Rev. FREDERICK DENISON MAURICE, M.A., Professor of Moral Philosophy in the University of Cambridge. (For other Works by the same Author, see THEOLOGICAL CATALOGUE.)

SOCIAL MORALITY. Twenty-one Lectures delivered in the University of Cambridge. New and Cheaper Edition. Crown 8vo. 10*s*. 6*d*.

"*Whilst reading it we are charmed by the freedom from exclusiveness and prejudice, the large charity, the loftiness of thought, the eagerness to recognize and appreciate whatever there is of real worth extant in the world, which animates it from one end to the other. We gain new thoughts and new ways of viewing things, even more, perhaps, from being brought for a time under the influence of so noble and spiritual a mind.*"—Athenæum.

THE CONSCIENCE: Lectures on Casuistry, delivered in the University of Cambridge. New and Cheaper Edition. Crown 8vo. 5*s*.

The Saturday Review *says:* "*We rise from them with detestation of all that is selfish and mean, and with a living impression that there is such a thing as goodness after all.*"

MORAL AND METAPHYSICAL PHILOSOPHY. Vol. I. Ancient Philosophy from the First to the Thirteenth Centuries; Vol. II. the Fourteenth Century and the French Revolution, with a glimpse into the Nineteenth Century. New Edition and Preface. 2 Vols. 8vo. 25*s*.

Morgan.—ANCIENT SOCIETY: or Researches in the Lines of Human Progress, from Savagery, through Barbarism to Civilisation. By LEWIS H. MORGAN, Member of the National Academy of Sciences. 8vo. 16*s*.

Murphy.—THE SCIENTIFIC BASES OF FAITH. By JOSEPH JOHN MURPHY, Author of "Habit and Intelligence." 8vo. 14*s*.

"*The book is not without substantial value; the writer continues the work of the best apologists of the last century, it may be with less force and clearness, but still with commendable persuasiveness and tact; and with an intelligent feeling for the changed conditions of the problem.*"—Academy.

Paradoxical Philosophy.—A Sequel to "The Unseen Universe." Crown 8vo. 7*s*. 6*d*.

Picton.—THE MYSTERY OF MATTER AND OTHER ESSAYS. By J. ALLANSON PICTON, Author of "New Theories and the Old Faith." Cheaper issue with New Preface. Crown 8vo. 6*s*.

Picton—*continued.*

CONTENTS :—*The Mystery of Matter—The Philosophy of Ignorance—The Antithesis of Faith and Sight—The Essential Nature of Religion—Christian Pantheism.*

Sidgwick.—THE METHODS OF ETHICS. By HENRY SIDGWICK, M.A., Prælector in Moral and Political Philosophy in Trinity College, Cambridge. Second Edition, revised throughout with important additions. 8vo. 14*s.*

A SUPPLEMENT to the First Edition, containing all the important additions and alterations in the Second. 8vo. 2*s.*

"*This excellent and very welcome volume. . . . . Leaving to metaphysicians any further discussion that may be needed respecting the already over-discussed problem of the origin of the moral faculty, he takes it for granted as readily as the geometrician takes space for granted, or the physicist the existence of matter. But he takes little else for granted, and defining ethics as 'the science of conduct,' he carefully examines, not the various ethical systems that have been propounded by Aristotle and Aristotle's followers downwards, but the principles upon which, so far as they confine themselves to the strict province of ethics, they are based.*"—Athenæum.

Thornton.—OLD-FASHIONED ETHICS, AND COMMON-SENSE METAPHYSICS, with some of their Applications. By WILLIAM THOMAS THORNTON, Author of "A Treatise on Labour." 8vo. 10*s.* 6*d.*

The present volume deals with problems which are agitating the minds of all thoughtful men. The following are the Contents:—I. Ante-Utilitarianism. II. History's Scientific Pretensions. III. David Hume as a Metaphysician. IV. Huxleyism. V. Recent Phase of Scientific Atheism. VI. Limits of Demonstrable Theism.

Thring (E., M.A.).—THOUGHTS ON LIFE-SCIENCE. By EDWARD THRING, M.A. (Benjamin Place), Head Master of Uppingham School. New Edition, enlarged and revised. Crown 8vo. 7*s.* 6*d.*

Venn.—THE LOGIC OF CHANCE: An Essay on the Foundations and Province of the Theory of Probability, with especial reference to its logical bearings, and its application to Moral and Social Science. By JOHN VENN, M.A., Fellow and Lecturer of Gonville and Caius College, Cambridge. Second Edition, rewritten and greatly enlarged. Crown 8vo. 10*s.* 6*d.*

"*One of the most thoughtful and philosophical treatises on any subject connected with logic and evidence which has been produced in this or any other country for many years.*"—Mill's Logic, vol. ii. p. 77. Seventh Edition.

NATURE SERIES.

THE SPECTROSCOPE AND ITS APPLICATIONS. By J. N. LOCKYER, F.R.S. With Illustrations. *Second Edition.* Crown 8vo. 3*s.* 6*d.*

THE ORIGIN AND METAMORPHOSES OF INSECTS. By Sir JOHN LUBBOCK, M.P., F.R.S. With Illustrations. Crown 8vo. 3*s.* 6*d.* *Second Edition.*

THE TRANSIT OF VENUS. By G. FORBES, B.A., Professor of Natural Philosophy in the Andersonian University, Glasgow With numerous Illustrations. Crown 8vo. 3*s.* 6*d.*

THE COMMON FROG. By ST. GEORGE MIVART, F.R.S. Illustrated. Crown 8vo. 3*s.* 6*d.*

POLARISATION OF LIGHT. By W. SPOTTISWOODE, LL.D., President of the Royal Society. Illustrated. *Second Edition.* Crown 8vo. 3*s.* 6*d.*

ON BRITISH WILD FLOWERS CONSIDERED IN RELATION TO INSECTS. By SIR JOHN LUBBOCK, M.P., F.R.S. Illustrated. *Second Edition.* Crown 8vo. 4*s.* 6*d.*

THE SCIENCE OF WEIGHING AND MEASURING. By H. W. CHISHOLM, Warden of the Standards. Illustrated. Crown 8vo. 4*s.* 6*d.*

HOW TO DRAW A STRAIGHT LINE: A Lecture on Linkages. By A. B. KEMPE, B.A. Illustrated. Crown 8vo. 1*s.* 6*d.*

LIGHT: A Series of Simple, Entertaining and Useful Experiments in the Phenomena of Light for the Use of Students of every Age. By ALFRED M. MAYER and CHARLES BARNARD. With Illustrations. Crown 8vo. 2*s.* 6*d.*

SOUND: A Series of Simple, Entertaining and Inexpensive Experiments in the Phenomena of Sound, for the Use of Students of every Age. By A. M. MAYER, Professor of Physics in the Stevens Institute of Technology, &c. With numerous Illustrations. Crown 8vo. 3*s.* 6*d.*

SEEING AND THINKING. By Prof. W. K. CLIFFORD, F.R.S. With Diagrams. Crown 8vo. 3*s.* 6*d.*

(*Others to follow.*)

MACMILLAN AND CO., LONDON.