MICROSCOPICAL EXAMINATIONS, &c

OF THE

THAMES AND OTHER WATERS.

1852.

REPORTS

MADE

TO THE DIRECTORS

OF

THE LONDON (WATFORD) SPRING WATER COMPANY,

ON THE

RESULTS OF MICROSCOPICAL EXAMINATIONS

OF

The Organic Matters and Solid Contents of Waters supplied from the Thames and other Sources:

BY

EDWIN LANKESTER, M.D., F.R.S.
AND PETER REDFERN, M.D., F.R.C.S.L.

TOGETHER WITH

A Chemical Report on the Quality of Various Specimens of Water from Chalk Springs near Watford:

BY

THOMAS CLARK, M.D.
AND JOHN SMITH, M.D.

1852.

HUGHES, PRINTER,
KING'S HEAD COURT, GOUGH SQUARE.

PREFACE.

The information contained in the Reports which follow is the result of long, laborious, and costly investigations, and cannot fail to command the attention of all who are really anxious, that the inhabitants of the Metropolis should have within their reach a pure and wholesome water.

Most river water, and surface drainage water, is more or less contaminated, especially in warm weather, with decaying animal or vegetable matter, derived from manured land, faded blossoms, fallen leaves, decaying plants, or the sewage of towns.

Experience has proved, that no artificial means of filtration, now known or practised, can entirely remove such impurities. Rains cause river and surface water to become foul and muddy; and, in winter, such water is as cold as 33° or 34° Fahrenheit, while, in summer, it is as warm as 72° or 73° Fahrenheit.

The subterranean water of the Chalk Springs near

Watford was originally derived, and would be replenished or fed, from the rain falling upon the surface of the vast area, and percolating through the enormous mass of chalk hills around and above Watford.

The rain is absorbed by the surface chalk as fast as it falls, but by no means percolates down through the body of the chalk, which is from 700 to 900 feet thick, so rapidly to the lower depths. It goes down gradually and slowly, and in so doing displaces or drives out a portion of the water with which the pores of the lower mass of the chalk are filled. It would occupy many years, (probably two centuries,) before much of the rain, now falling, would reach the depth at which the water would be procured from Bushey Meadows.

In consequence of the water being held in this manner, for so long a time, in the amply aërated pores of the chalk, where every motion of the barometer brings it in contact with a change of atmospheric air, every vestige of organic matter must long since have left it,—the whole of the impurities caught in the descent of the rain through the surface of the ground is oxidized, the water becomes pure and bright, of the mean temperature of the atmosphere for the year, and is in fact spring water of admirable quality, characterized,—

1st, By being at the agreeable temperature, at all seasons of the year, of 52° Fahrenheit; or 18° colder in the summer, and 18° warmer in the winter, than river water.

2nd, By being utterly free from all organic, or putrescible animal, or vegetable matter.

3rd, By being always perfectly bright and fresh, and not affected, (like river water,) in this respect, by the heaviest rain, or the longest drought.

When first pumped from the well, the water is about $17\frac{1}{2}°$ of hardness, or contains in solution about $17\frac{1}{2}$ grains of chalk per gallon. By a simple and inexpensive process, which does nothing but withdraw 16 of these grains of chalk, without leaving anything else in the water, it becomes as soft as ordinary rain water, when collected from the roof of a house, without losing any of its brightness or freshness.

The temperature and purity of the water, after being raised from the Chalk Springs, will be maintained by the London (Watford) Spring Water Company, by pumping it through closed pipes, buried in the ground, into distributing reservoirs covered in a suitable manner, and by conveying the water to the consumers through similar pipes, constantly charged, so that the water may be drawn direct from the pipes without the intervention of a cistern.

The result of the elaborate investigations described in the following pages proves that the quality of the water at present supplied, or the quality of any water heretofore proposed to be supplied to the Metropolis, will not bear favourable comparison with the water which can be supplied from the subterranean Chalk Springs near Watford, in all the requisites for a town supply; namely, freedom from animal and vegetable matter,—softness,—freshness, brightness,—and agreeableness, and uniformity of temperature.

S. C. H.

19, Buckingham Street,
Oct. 11th, 1852.

INTRODUCTION

TO

THE MICROSCOPICAL REPORTS.

THE following Reports are the result of microscopical examinations of several waters, either supplied, or proposed to be supplied, to the public for domestic uses, and were drawn up at the request of the Directors of the LONDON (WATFORD) SPRING WATER COMPANY. The object of this Company is to procure for the Metropolis a supply of spring water, which they propose to bring from the neighbourhood of Watford.

The result of the microscopical examinations has been to manifest the freedom of the water the Company proposes to supply, from animal and vegetable matter, and its consequent desirableness for drinking, cooking, and other domestic purposes. Although not an entirely novel procedure, so extensive a series of microscopical examinations of water supplied to towns has not previously been laid before the public. Hitherto, it has been supposed, that chemical evidence was sufficient, as regards organic matter, for determining the purity or desirableness of a water for the purposes of life. The Chemist can however at best determine only the elements of which such matter is composed, but not the forms of animal or vegetable life which those elements assume. Hence the importance of microscopical examination, which not only indicates the forms of organic beings, but also the abundance and the character, whether injurious or harmless.

In presenting their Reports, the authors have thought it would tend to the better understanding of the subject, if they introduced illustrations of some of the forms of vegetable and animal life that are found in water, and which indicate the presence of impure matters. They have done this, as they know that there is a great deal of exaggeration about the size and nature of these beings on the one side, and scepticism as to their very existence on the other.

The illustrations in the Reports show only a few specimens of the objects observed; they are, with two exceptions, copied from the works of Ehrenberg, Dujardin, and Hassall, and may be regarded as types or examples of the various organic beings that inhabit impure waters.

As far as these researches go, it evidently appears, that the number and variety of organic beings are indications of the amount of organic and inorganic impurity of the waters in which they exist, and that the microscope may be made to aid in a most important manner the labours of the sanitary reformer.

Some of the bearings of these researches in relation to public questions appear to be of importance.

It has been decided by Parliament, that all water for the future supplied to London from the Thames must be obtained from above Teddington Lock. Although this is a great improvement upon a supply between the London and Vauxhall Bridges, it will be seen from the following Tables, that the Thames above Teddington Lock yields, under all circumstances, a water much contaminated with organic matter, and is there, at least, one of the last sources to which the Metropolis should look for a supply of pure water. The surface drainage of the most richly manured country in the world, and the sewers and drains of a hundred villages and towns, are emptied into the Thames above Teddington Lock.

Another point of some importance is, that the 'Metropolis Water Act, 1852,' requires that the Companies shall cover the reservoirs used to store and distribute their water. Now, although with regard to pure spring water, there can be little doubt that it is advisable so to cover such reservoirs as to maintain the uniform temperature of the water, and to keep it free from the chance of external contamination, yet with regard to river water, which always varies in temperature with the seasons, and is always more or less impure from organic matter, it is doubtful whether the placing such water out of the influence of the light and air will increase or decrease its impurities. It will be seen, as the result of these investigations, that the water of the wells in Brussels, although covered and unexposed to light, is contaminated with organic impurities.

The evident conclusion from the whole examination is, that such water as the Company proposes to obtain from the chalk formation near Watford, contains no organic matter, and is, of all sources that can supply a sufficient quantity, the purest within reach of London, and when previously softened, as proposed by the Company, will be best adapted for washing, cooking, and drinking.

As many persons may be anxious to make microscopical observations for themselves, a few directions are subjoined for enabling them to verify the results that are given in the following pages.

A half-gallon stoppered bottle, well cleaned and steamed, should be filled with the water to be examined; the bottle should be held alternately before white and black surfaces in a good light, and the appearance of the fluid noted down. It must then be allowed to stand in a cool shady place for 12 or 24 hours, and on re-examination as before, the living creatures visible to the naked eye will be discovered, and the character of the deposit ascertained. The animalcules visible to the naked eye are to be removed with a small glass tube used as a pipette, and if the deposit be considerable, successive portions of it must be abstracted in the same manner also for microscopical examination. If the deposit be scarcely visible, the greater part of the supernatant fluid must be carefully removed with a siphon, and the deposit washed out into a wine-glass with the last one or two ounces of the fluid, from which it can then be removed in the same way as a more copious deposit. After being placed between two slips of glass, all the living animals and other structures named in the Tables can be shown by a good achromatic microscope having powers of 250 and 500 linear diameters. Such an instrument, of French manufacture, can be obtained for from £4. to £6., and the larger objects may be distinctly seen by glasses which may be procured for much less.

October 1st, 1852.

REPORT

MADE TO

THE DIRECTORS OF THE LONDON (WATFORD) SPRING WATER COMPANY,

ON

THE ORGANIC CONTENTS FOUND BY THE MICROSCOPE IN WATERS SUPPLIED FROM THE THAMES AND OTHER SOURCES.

BY EDWIN LANKESTER, M.D., F.R.S.

Modern science has placed in the hands of investigators two principal means of ascertaining the purity of waters, and their adaptation to the purposes for which they are employed by man,—chemical analysis and the microscope. By means of the former, the saline or inorganic contents dissolved in water are ascertained, whilst by the latter instrument the organic beings which are nourished and live in water are made apparent.

The observations contained in the following Report have been principally confined to the application of the microscope for the purpose of ascertaining the particular forms of plants and animals found in the waters named.

Although in perfectly pure water it would be impossible that either plants or animals should live, yet in a state of nature water is seldom met with that does not contain the elements out of which plants and animals are formed. Of the various elements of which the whole vegetable and animal kingdoms are built up, there are four which are universally present in plants and animals, and which must consequently be always present in waters where either plants or animals exist. These are—carbon, hydrogen, oxygen, and nitrogen. These elements do not, however, occur in their pure form, nor would they, if pure, subserve the nutrition of organic beings; but they are found more especially in the form of carbonic acid and ammonia. The first substance contains carbon and oxygen, the last nitrogen and hydrogen. Just in proportion as these substances abound *within certain limits* will be the abundance of vegetable life, and just in proportion to the vegetable life will be the amount of animal life. Plants derive their nourishment from carbonic acid and ammonia,—animals derive their nourishment from plants.

The natural source of carbonic acid and ammonia in water is the atmosphere. Water exposed to the atmosphere, as in rivers, and rain-water, contain these substances. An additional source of these substances, in rivers and wells, is the presence of organic matter in a state of decomposition. Wherever decaying vegetable and animal substances or excretions are found, they give off these gases,—hence one of their uses as manures. In proportion therefore to the introduction from without of organic matters, will be the increase of organisms within the water; and as in climates like our own it is only at certain seasons of the year that vegetation is active, there will always be in such waters a quantity of vegetable and animal matter in a state of decay, always disagreeable, and under some circumstances likely to be highly injurious to the health of those who consume it in their diet.

The sources of the organic matter of the River Thames are sufficiently obvious on its banks, where it is found that the sewers of almost every town, village, and house in its vicinity, empty themselves into this river. That the organic matter thus discharged into this water is not all decomposed and taken up by its vegetation, is proved by the great deposits of mud above the influence of the tide, and which consists principally of animal and vegetable matter in a state of decay.

The sources of these substances when they exist in wells are soakage from manured lands, or percolations from neighbouring sewers or cesspools. Many of the shallow wells in London present from this cause a large amount of organic matter, and of those saline substances which are the result of chemical changes going on in the organic matter in contact with the oxygen of the air. The saline substances thus formed are principally salts of nitric acid, which is formed by the union of the nitrogen of the organic substance with the oxygen of the air. These salts are known to have a very depressing effect upon the human system.

When plants and animals die, and their tissues are exposed to the action of water, many other substances are formed besides those resulting from the compounds of the above-mentioned elements. Both sulphur and phosphorus are found in small quantities in animal and vegetable bodies, and sulphuric and phosphoric acids amongst the saline ingredients of water. Through these substances the gases known as sulphuretted and phosphuretted hydrogens, more especially the former, are produced. The action of these gases on the system is very depressing, and they give the disagreeable odour to water that has been kept for a few days. Very small quantities of organic matter, kept in contact with the salts of sulphuric acid, as I have shown in my work on the Mineral Springs of Askern, will serve to produce quantities of sulphuretted hydrogen that would destroy all vegetable or animal life in the waters which contained it.

Besides the elements carbon, hydrogen, oxygen, and nitrogen, and those of sulphur and phosphorus, there are others contained in water which exert an influence on the life of particular plants. It is well known that sea-weeds will only live in water containing chloride of sodium (common salt). Land and fresh-water plants require potash, whilst a large number of plants flourish in proportion as the salts of lime or silica are present. Where these salts exist they encourage the growth of certain plants, and with them animals which would have no existence without them.

These facts will explain the difference observed in different waters with regard to the presence of organic life, and the existence of the latter must be regarded as one of the best tests of the degree of impurity of the waters in which they are found.

Before speaking of the results of a microscopic examination of the waters supplied by the Water Companies from the River Thames and other sources, I may refer to those facts with regard to its condition which are obvious to every observer. That it must contain large quantities of organic matter, is made evident by the sewage of the towns on its banks being emptied into it. It runs also through a highly cultivated district of England, so that the surface drainage which necessarily falls into it is more than usually charged with organic matters from the manure employed in cultivation. As a proof of this, it may be stated that vegetation has been observed to be more prolific in the river after heavy rains, and Dr. Angus Smith states that at such times it is richer in saline contents.

Throughout the whole extent of the Thames from which the present Water Companies obtain their supplies, (including the Lambeth Company at Thames Ditton,) banks of a black deposit exist, which consist principally of animal and vegetable *débris* in a state of decomposition, and which abounds with animal and vegetable life.

In the summer season the Thames abounds with aquatic flowering plants belonging to various species, which grow from the beds of mud on its sides, and indicate by their luxuriance the large supply of manure they receive. Various species of Confervæ are also abundant.

The Thames also abounds with fish and various forms of invertebrate animals easily detected with the naked eye. Mollusca belonging to the genera

Limneus, Planorbis, Unio, Cyclas, Paludina, Neritina, and others, are very numerous. The larvæ of almost innumerable forms of insects are found in its mud, and on the stones on its banks. Visible forms of Annelides, amongst which may be mentioned the common leech, with other species of the same genus, occur in great numbers. Various species of water-spider are common. Crustaceans, from the larger forms of the fresh-water shrimps down to the microscopic Cyclops and Daphnia, which, scarcely seen singly, by their numbers frequently give a yellow colour to the water, are amongst the most abundant forms of its animal life. Of the Radiate animals, the Hydra with Cristatella and other forms of Zoophytes are frequently present, whilst the fresh-water sponge (Spongilla fluviatilis) is found in some places in great abundance, and its spiculæ form a part of the deposit of the purest specimens of the water.

The plants and animals whose existence and true nature are revealed by the microscope are much more numerous than those discoverable by the naked eye. The mode of proceeding in order to examine these creatures as they exist in waters supplied by the London Companies was as follows: The waters were collected and sent in bottles numbered and labelled, so that they could be identified. After having been placed in various situations, they were examined as to whether any creatures visible to the naked eye were floating about. The clear water was then poured off with the exception of about two ounces, which contained whatever of animal and vegetable matter had been deposited, as well as the majority of the living organisms to be found in the water. These deposits consisted of decomposing animal and vegetable matter, and also living plants and animals.

A large quantity of the deposit was composed of disorganized matter, sometimes quite black, at other times of a brown or a light yellow colour. Frequently in the midst of this matter could be seen portions of animal and vegetable tissue in a less decomposed state. Portions of woody tissue, spiral vessels, cotton hairs, fragments of leaves, and parts of small branches, seeds of water-plants, and pieces of wood, were frequently observed. Of animal remains, the legs and cases of the Crustacea were most common, but pieces of the skins of the larvæ of flies, as well as the hairs of animals and even portions of muscular fibre, were not unfrequent. It is from such substances as these that living organisms derive their food, plants the gases which they need, and some animals their usual nutriment.

The PLANTS discovered by the microscope belonged to the families Confervaceæ, Desmidieæ, Diatomaceæ, and Fungi.

The Confervaceæ are generally inhabitants of fresh water. Although many of them grow in pure waters, certain forms of them are adapted to almost every condition of impurity. Thus I have found Calothrix nivea and species of Oscillatoria in the sulphureous waters of Harrowgate, Askern, Moffat, and of other places where these springs exist. The same plants are also present in waters highly charged with night soil or the refuse of towns. The portions of these plants found in the Thames water belonged to those forms which are generated in the above circumstances, and may certainly be regarded as indicative of the impurity of the water in which they were found.

The Desmidieæ are all of them microscopic plants, which are found in most abundance in still waters; they would therefore not be expected to occur in abundance in waters procured from a running stream. Several species, however, have been found in the waters supplied by the Companies, and great numbers in the mud of the Thames procured in quiet spots far above Teddington Lock.

In the case of water procured from the Lambeth Company's supply, which had stood for a few days exposed to the air of a room, the bottom of the vessel was observed to be green, and on examination this colour was found to depend on an immense quantity of a small Desmidian, the Closterium setaceum. Fig. 7 is an example of one of the most frequent of these plants.

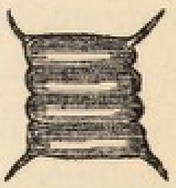

Fig. 7.—Scenedesmus quadricauda, magnified 300 diameters.

The Fungi are plants rather of the land than of the water. They are found wherever animal or vegetable matter is decomposing in the air. Some of the species, however, are found in the water, and in most of the waters which I have examined the well-known fibrillæ of these plants have presented themselves. They were in considerable numbers in the waters taken from covered wells 94 feet in depth, in the city of Brussels.

The Diatomaceæ are by far the most abundant

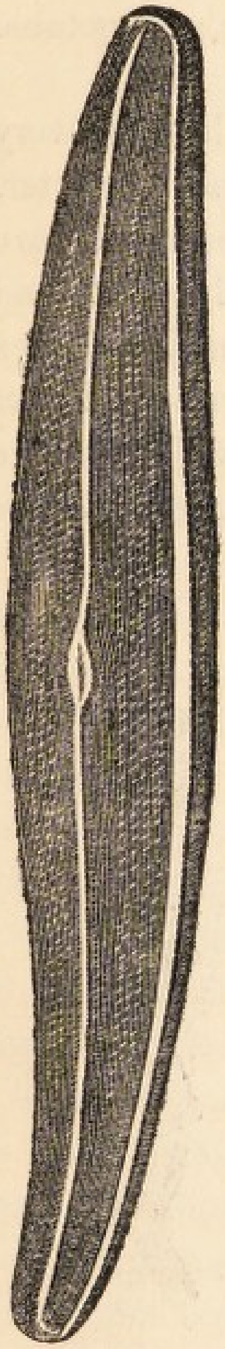

Fig. 1.—Navicula Hippocampus, magnified 470 diameters.

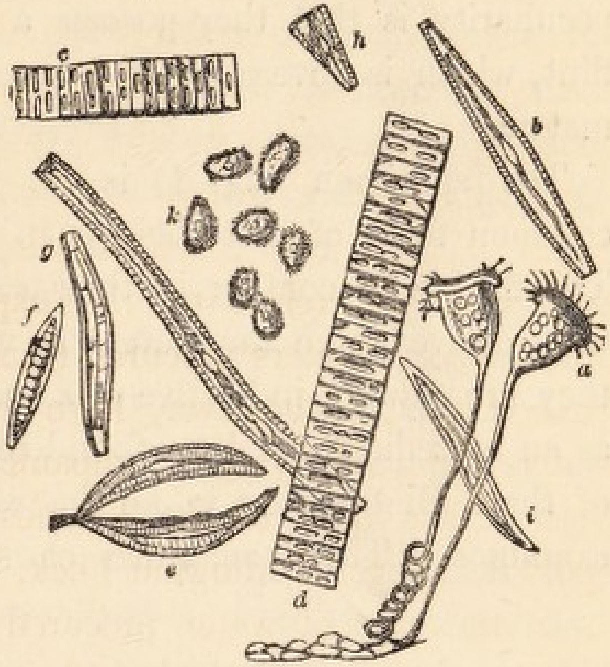

Fig. 2.

(*a*) Vorticella nebulifera,
(*b, i*) Species of Navicula,
(*c, d*) Fragilaria pectinalis,
(*e*) Cocconema cymbiforme,
(*g*) Navicula arcus,
(*h*) Frustule of Gomphonema,
(*k*) Infusoria,
magnified 100 diameters.

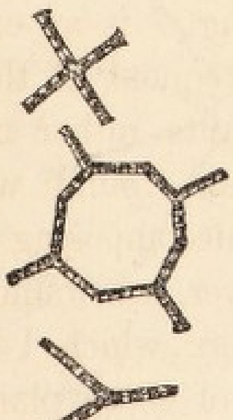

Fig. 3.—Bacillaria elongata, magnified 200 diameters.

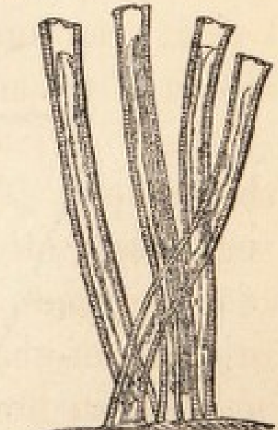

Fig. 4.—Synedra Ulna, magnified 100 diameters.

forms of plants of a microscopic size found in water. These beings are endowed with movement, and were at one time regarded as animals. Their distinguishing peculiarity is that they possess a solid framework of flint, which is covered with a membrane of vegetable matter.

The specimen (fig. 1) is an example of a very common form of these beings, in the Thames water. The flint they contain in their substance must have been derived from the waters in which they live, and they are always indicative of a water containing silex as an ingredient. I have found some form or another of these Diatomaceæ in all the waters which I have examined. They sometimes clothe other substances

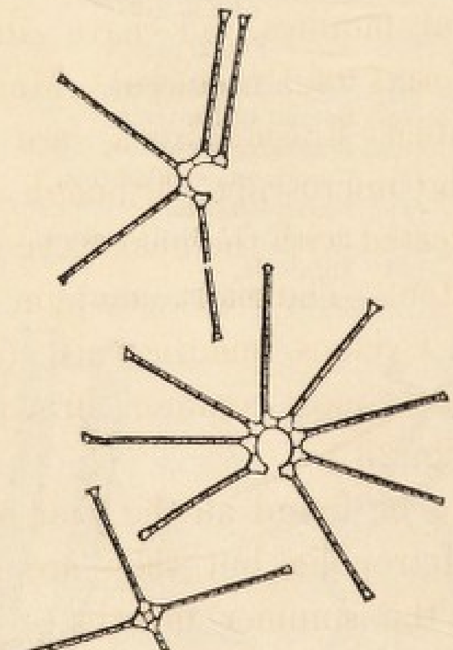

Fig. 5.—Asterionella formosa, magnified 100 diameters.

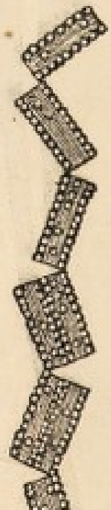

Fig. 6.—Bacillaria vulgaris, magnified 100 diameters.

in clusters, as is the case with the Synedra Ulna (fig. 4). As met with in the water, they are mixed with the other forms of animal and vegetable life as presented in fig. 2. The mode of development of these plants is not known, but it is probable that they are propagated by minute spores which evade the filtration to which waters are usually subjected. (Figs. 3, 4, 5, 6.)

It is not always easy to identify the spores or reproductive cells of individual species of plants, but in almost every instance I found amongst the decomposing *débris* of the waters examined the spores of some of the lower forms of plants.

The microscopic forms of animal life found in the waters sent me for examination were very numerous, and belonged to several families. I have already spoken of the visible forms of Crustacea. Many of the smaller kinds, called Entomostraca, are only discernible by aid of the microscope, although some species can be easily detected with the naked eye when floating through the water. The most common form of these creatures is the Cyclops quadricornis. (Figs. 20, 21, and 22.) The next most common form is the Chydorus sphericus. (Fig. 23.)

These creatures are to be found all the year round in waters about the Metropolis, but they are more especially abundant in the summer months. They are carnivorous in their habits, and indicate not only that waters contain organic matters, but that plants have been formed, and that these plants are inhabited by smaller animals on which they prey.

But few of the true insects in their perfect state are found in the filtered waters supplied for use in Lon-

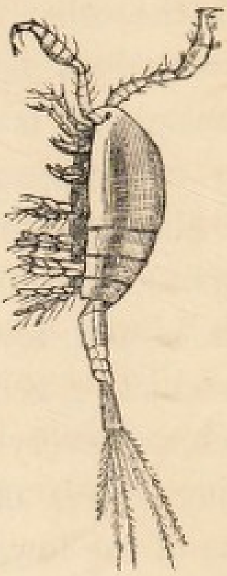

Fig. 21.—Cyclops quadricornis (male), magnified 50 diameters.

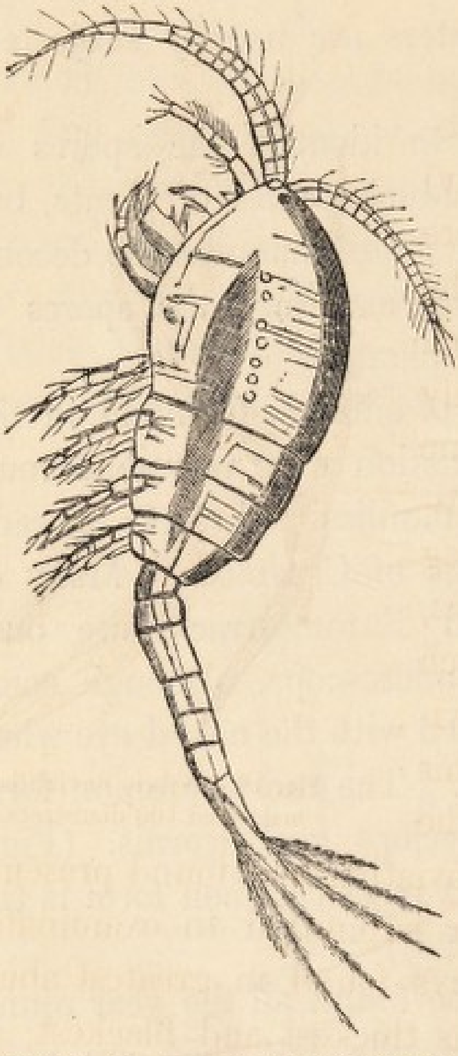

Fig.20.—Cyclops quadricornis (female), magnified 50 diameters.

Fig. 22.—Cyclops (young), magnified 50 diameters.

Fig. 23.—Chydorus sphericus, magnified 50 diameters.

don, although water-beetles and other forms abound in the open Thames. The eggs and larvæ of insects, however, are not uncommon. Many of the Neuropterous and Dipterous insects deposit their ova on plants in the water, and after they are hatched the larvæ live on the plants and on the organic deposits of the river. Some plants obtained this month (May) in the River Thames were literally covered with the larvæ of a small fly. Such larvæ are not always easily discoverable from some permanent forms of articulated animals belonging to the family of Annelides, a family to which the leech belongs. A creature evidently related to this family, and known by the erroneous name Vibrio fluviatilis, was found present in every specimen of water submitted to examination. These creatures are always found in greatest abundance where the deposit is thickest and blackest, and are most numerous where the waters contain the largest quantity of organic matters in a state of decay.

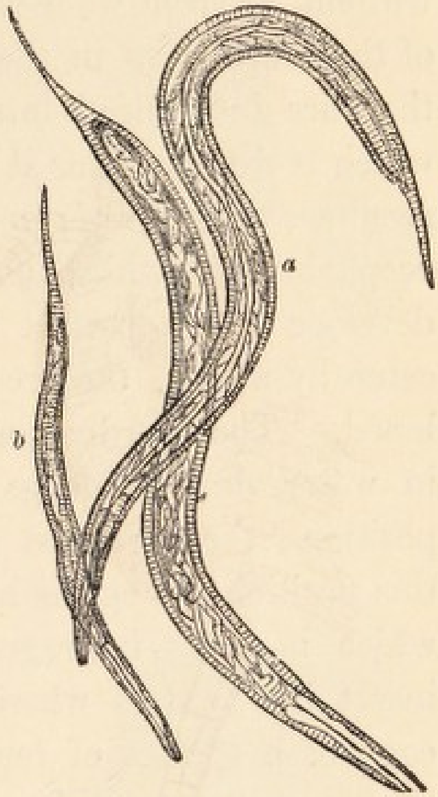

Fig. 19.—Vibrio fluviatilis, magnified 100 diameters.

The creatures mentioned last resemble some of the forms of Entozoa or worms found inhabiting man's body, and it is a grave question for consideration, from whence these creatures are introduced into the body. It is almost certain that they are not generated *de novo* in the human body, and consequently that their eggs or some form of their existence are introduced from without. From what is already known of the history of these creatures in the lower animals, it is probable they are introduced into the system with the water which is drunk. Thus it is known that the stickleback swallows the eggs of a species of Entozoa called Bothriocephalus, but whilst inside the fish these eggs never develope into a perfect Entozoon; but if the fish is eaten by a bird, the creature becomes perfectly developed. The Gordius or hair-worm deposits its eggs in water, but the eggs are not developed in this position; they are first swallowed by insects, and in this position the egg is hatched, produces the Gordius which becomes impregnated, and escapes from the insect into waters where it deposits its eggs. The eggs of a species of tape-worm, when swallowed by the rat or mouse, will not produce perfect tape-worms in the inside of these creatures, but if they are eaten by the cat or dog, then the perfect tape-worm is produced. Many other instances might be quoted to show that it is not improbable that some of the forms of animal life which abound in waters containing organic matter, are transitionary states of those permanent forms of animals which infest the body, and sometimes even destroy human life.

Of the animals made conspicuous by the microscope, none have more varied habits, or present so high an

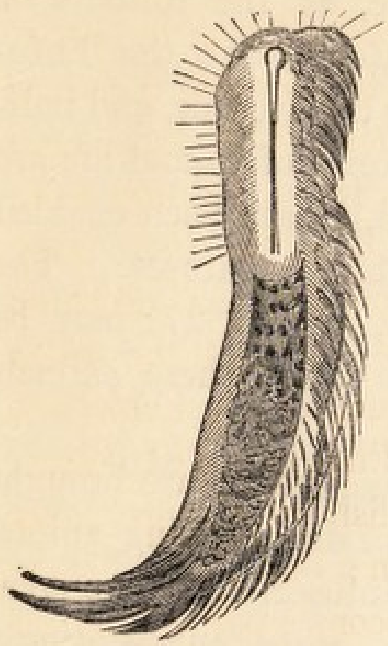

Fig. 24.—Chætonotus Larus, magnified 500 diameters.

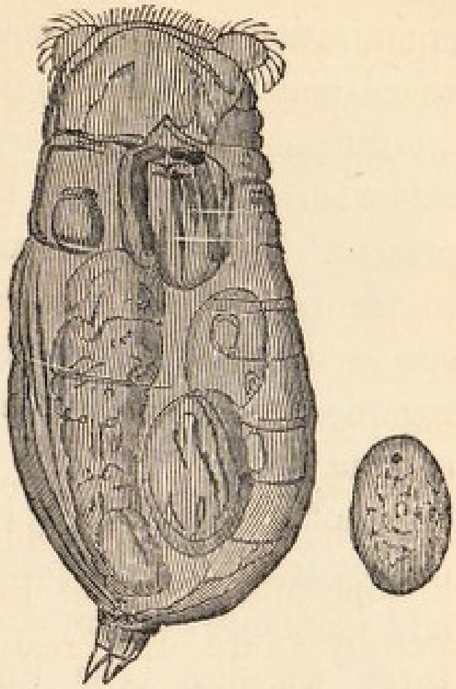

Fig. 25.—Notommata aurita, magnified 260 diameters.

Fig. 26.—Euchlanis brevispina, magnified 200 diameters.

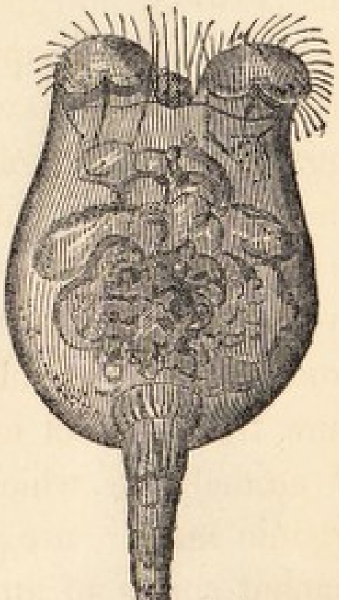

Fig. 27.—Brachionus urceolaris, magnified 160 diameters.

organization for their small size, as the Rotifers or wheel-animalcules. These creatures, like the Entomostracous Crustacea, are mostly carnivorous, and indicate where they are, that lower forms of animal life are present. In the waters examined, I have been enabled to identify twelve species of these creatures. The species represented by figs. 24, 25, 26, 27, may be regarded as types of the forms which these animals assume.

Amongst the first organic beings which are brought into existence by the presence of decomposing animal and vegetable matters are the Infusoria. These creatures, which a little time ago were unhesitatingly

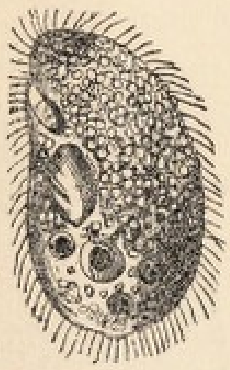

Fig. 11.—Kolpoda cucullus, magnified 300 diameters.

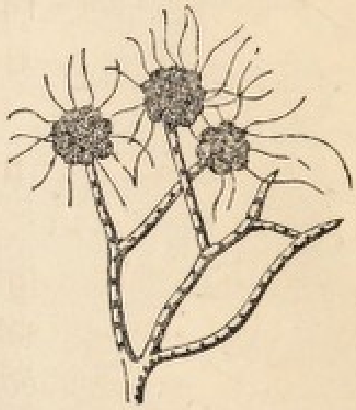

Fig. 13.—Anthophysa Mülleri, magnified 300 diameters.

Fig. 14.—Paramæcium chrysalis, magnified 100 diameters.

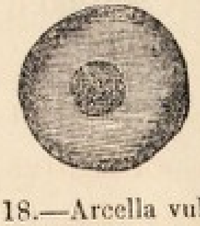

Fig. 18.—Arcella vulgaris, magnified 200 diameters.

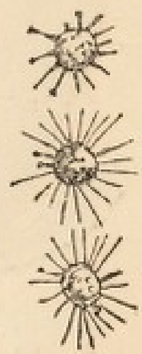

Fig. 17.—Actinophrys Sol, magnified 300 diameters.

classed as animals, must now, many of them, be regarded as plants, as the function they perform in the waters in which they are found is to organize the carbonic acid, ammonia, and other gases which are given off during the decomposition of organic substances. To plants rather than to animals we may refer such forms as those presented by figs. 11, 13, 14, 17, and 18. Although there is no doubt that these beings are wisely adapted to take up those matters which would be more injurious were they not present, it should be recollected that wherever they exist, they indicate the presence of substances which cannot but be injurious when taken into the human system.

Of the animal character of many of the creatures belonging to this family there can be no doubt. Such are the group of

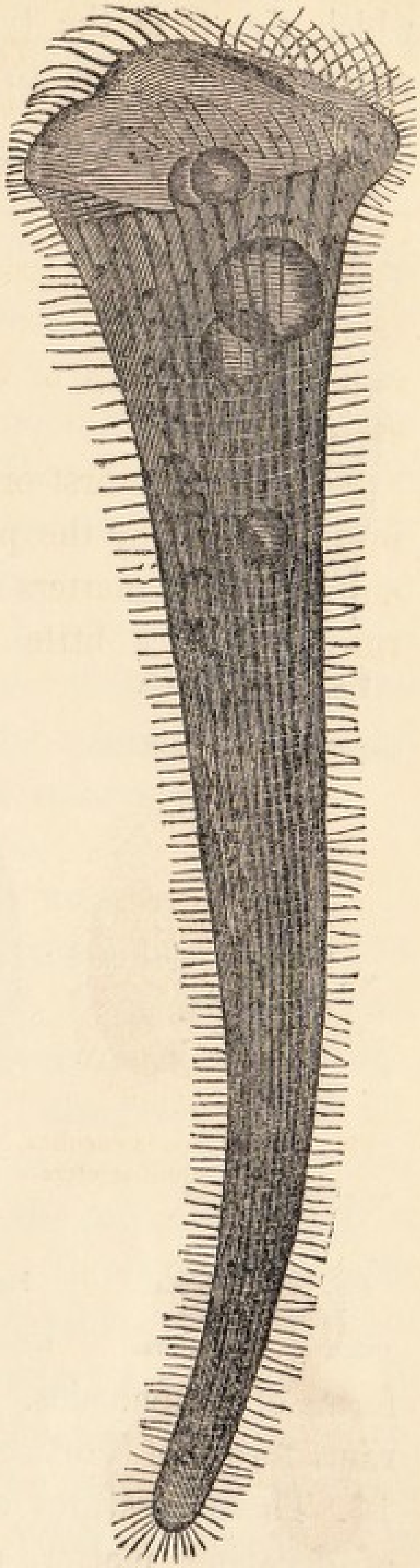

Fig. 8.—Stentor Mülleri, magnified 150 diameters.

which fig. 8 is the type, and which, when in the water, can be seen to devour many of the smaller

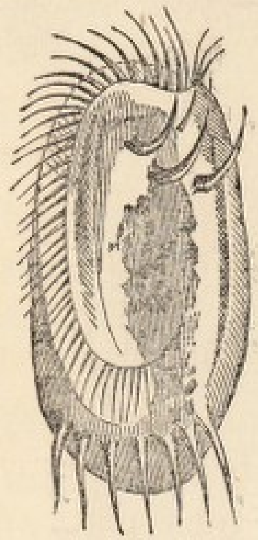

Fig. 15.—Plesconia vannus, magnified 320 diameters.

Fig. 12.—Vorticella, magnified 100 diameters.

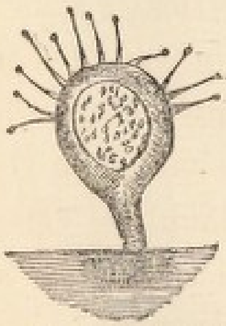

Fig. 16.—Acineta tuberosa, magnified 150 diameters.

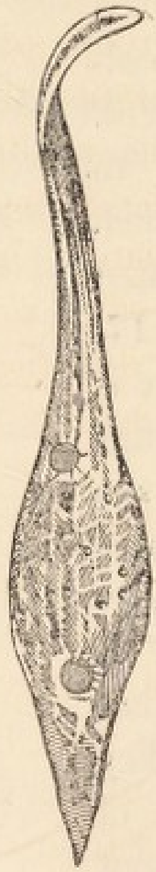

Fig. 9.—Dileptus folium, magnified 400 diameters.

Fig. 10.—Dileptus granulosus, magnified 400 diameters.

forms of animalcules. Such appear also to be the various forms of Vorticellinæ, fig. 2 *a*, fig. 12, and fig. 16. These creatures are found adhering to portions of decaying matter, and living on the more plant-like forms referred to above. Many of the Infusoria are adapted to living in circumstances which would destroy the life of higher animals. Thus with the plants of the sulphureous waters I invariably found associated forms of Infusoria adapted to live upon the plants growing under these circumstances. Such forms as those presented by figs. 9, 10, and 15, are found where decomposition of organic matter is going on most actively.

There is another group of animals which are perhaps lower in organization than the Infusoria, and which contribute to the adulteration of the water of rivers; these are the Sponges. The fresh-water Sponge (Spongilla fluviatilis) has the solid parts of its body made up of siliceous (flinty) spicula, and when the animal part dies the spicula remain, and are often presented under the microscope.

The waters examined by me were as follows:

1. New River water, three quart bottles of which were sent me from 19, Buckingham Street, on the 9th of May; they were dated May 6th, and signed James Fry. I also received from Dr. Clark a pint bottle of water, which he stated he had procured from the top of the water at the spring at Chadwell. In all these cases the water presented a considerable deposit of a light brown colour after standing a few hours. In two bottles out of the four, small entomostracous Crustacea could be seen floating about with the naked eye. With the exception of the West Middlesex, the New River water pre-

sented the greatest number of forms of animal and vegetable life.

2. Water of Lambeth Company supplied from Thames Ditton. Six specimens of this water were sent me: three labelled May 6th, and sent to my house May 8th; two sent May 22nd, and one May 29th, all signed James Fry. These specimens differed little from each other either in the general appearance of the water, the amount of deposit, or the number of species of plants and animals found in the deposit. The deposit was not so dark in colour nor in so large quantity as in either the New River, West Middlesex, or Surrey Sand waters, but it presented, within three species, as many forms of animal and vegetable life as any of them.

3. West Middlesex Company. Three specimens of this water were sent me, and dated May 8th, and signed James Fry. Single specimens of a small entomostracous crustacean were seen floating about the water. The deposit was of a light brown, and considerable in quantity. Of all the waters examined it presented the greatest variety as well as the greatest number of forms of plants and animals. When exposed for several days to the action of light, the vegetation of Confervæ and other plants at the bottom of the vessel was greater in this water than in any of the others I received.

4. Waters collected from the Surrey Sands near Farnham, proposed by the Hon. W. Napier,

and adopted by the Board of Health. They were sent to my house on the 15th and 16th of May, and examined by me at various dates from the 17th of May to the 5th of June. They were marked as follows: B. S. 1, Bramshot; B. S. 2, Barford Mills; B. S. 3, Cosford House; B. S. 4, Sweet Water Pond; B. S. 5, Northfleet. They had all a light yellow colour, a rather plentiful dark brown deposit, and, on exposure to light, the bottom of the vessel presented a green appearance, from the growth of a species of Conferva. Although the deposit was much the same, the variety of species of animals and plants found in these waters varied considerably. Thus

B. S. 1	gave	24	species.
B. S. 2	,,	21	,,
B. S. 3	,,	11	,,
B. S. 4	,,	10	,,
B. S. 5	,,	10	,,

These waters contained fewer Diatomaceæ and a larger number of infusory animalcules than any of the others with the exception of the West Middlesex.

5. Water from wells at Brussels. There were three green glass bottles-full sent: the first, labelled "No. I., from a deep well at Brussels 94 feet;" another, "No. II., from a well in the middle of Brussels, Place des Barricades,

54 feet deep. May 14, 1852. 3." The label of the third was lost after it reached my house. All these waters presented a copious deposit, which consisted of crystals, part of which were dissolved up by hydrochloric acid, and part resisted this agent. The former were probably carbonate of lime. Amongst the deposit were portions of decomposing vegetable matter and a certain number of plants and animals. The water having been obtained from deep wells and kept in dark glass bottles was not in a favourable condition for the development of organic beings.

6. Grand Junction Company. The water was obtained from the pipe and cistern at 22, Old Burlington Street. The water was examined from the pipe, from the cistern, and after it had been submitted to the action of the house filter. This water did not present so great a variety of forms as many of the others, but the forms that presented themselves were very numerous, especially the Diatomaceæ. Even after the most careful filtering by one of Lipscombe's filters, it presented the following objects:

1. Portions of woody fibre.
2. Navicula elongata (Fig. 3, p. 9).
3. Actinophrys Sol (Fig. 17, p. 16).
4. Numerous Monadinæ (Figs. 2, *k*, p. 9).
5. Kolpoda cucullus (Fig. 11, p. 16).
6. Species of Diatomaceæ (Figs. 1—5, p. 9, 10).
7. Uvella virescens.

7. Watford Spring Water. Of this I have examined several specimens, softened and unsoftened, sent me by Dr. Clark from 19, Buckingham Street, brought by Mr. Dugald Campbell. In some of the first of these specimens, traces of organic matter were found, but after further examination it was discovered that this was probably owing to the difficulty of obtaining specimens from an open spring free from organic matter. In specimens collected with care, and especially when softened, it was found as free from organic matter as distilled water itself.

June, 1852.

Tabular Arrangement of the Results of the Examination of the Waters referred to in the preceding Report.

The × in the columns denotes the presence of the species or substance.

List of Species, with references to Figures.		NAMES OF WATERS.						
		New River.	Lambeth (Thames Ditton).	West Middlesex (Chiswick).	Surrey Sand.	Well-water from Brussels.	Grand Junction.	Watford Spring Water.
PLANTS.								
1. Decaying vegetable matter	. .	×	×	×	×	×	×	
Confervæ.								
2. Fibres of various species	. .	×	×	×	×	×		
3. Oscillatoria (species)	. .	×	×	×	×	. .	×	
4. Spirogyra (species)	. .	. .	. .	. .	×			
5. Sphærozyga spiralis	. .	. .	. .	. .	×			
6. Zygnæma (species)	. .	. .	. .	×				
7. Spores of Confervæ	. .	. .	. .	. .	. .	. .	×	
8. Hæmatococcus (species)	. .	. .	. .	. .	×			
Desmidieæ.								
9. Scenedesmus quadricauda	Fig. 7	. .	. .	×	×	. .	×	
10. Staurastrum brachiatum	. .	. .	. .	×				
11. Euastrum elegans	. .	. .	. .	. .	×	. .	×	
12. Closterium acerosum	. .	. .	. .	. .	×			
13. ——— setaceum	. .	×	×					
14. Docidium Ehrenbergii	. .	. .	. .	. .	×			
Fungi.								
15. Mycelium of Fungi	. .	×	×	×	×	×		
Diatomaceæ.								
16. Navicula Hippocampus	Fig. 1	×	. .	×				
17. Various species of Naviculæ	Fig. 2	×	×	. .	×			
18. Synedra Ulna	Fig. 4	×	×	×				
19. Bacillaria elongata	Fig. 3	. .	. .	×	. .	. .	×	
20. Navicula lanceolata	. .	. .	×	×				
21. Bacillaria (species)	Fig. 6	×						
22. Fragilaria rhabdosoma	. .	×	. .	×	×	. .	×	
23. ——— pectinalis	Fig. 2	×	. .	×				
24. Asterionella formosa	Fig. 5	×	×	×	. .	. .	×	
25. Navicula Phœnicenteron	. .	×						
26. Gomphonema (species)	. .	. .	. .	×	×			
27. Various species	. .	×	×	×	×	×	×	
ANIMALS.								
28. Portions of decaying animal matter	. .	×	×	×	×	×	×	
Crustacea.								
29. Cyclops quadricornis	Figs. 20, 21, 22	×	. .	×				
30. Chydorus sphæricus	Fig. 23	×	. .	. .	. .	×	×	
Insecta.								
31. Larvæ of Tipulæ	. .	×	. .	. .	×			
Annelida.								
32. Two species (small)	Fig. 19	×	×	×	×	×	×	
33. Large species	Fig. 19	×	. .	. .	×			
Rotifera.								
34. Brachionus urceolaris	Fig. 27	. .	×	×				
35. Plagiognathus laciniatus	. .	×	×	×	. .	. .	×	
36. Salpina brevispina	. .	×	×					
37. Vaginicola crystallina	. .	×						
38. Tardigrada	. .	×	. .	. .	. .	. .	×	
39. Euchlanis oblonga	Fig. 26	×						
40. Rotifera	. .	×	×	×				
41. Notommata aurita	Fig. 25	×	. .	×	×			
42. Plagiognathus felis	. .	. .	×	×	×			
43. Chætonothus larus	Fig. 24	. .	×	×	×			
44. Notommata saccigera	. .	. .	×					
45. ——— longiseta	. .	. .	×					
46. Floscularia ornata	. .	. .	×					
47. Synchæta pectinata	. .	. .	×	. .	. .	. .	×	
Infusoria.								
48. Plesconia vannus	Fig. 15	×	×	×	×	×		
49. Species of Monadinæ	. .	×	×	×	×	×	×	
50. Species of Vorticella	Figs. 2 and 12	×	×	×	×	×	×	
51. Actinophrys Sol	Fig. 17	×	×	×	×	. .	×	
52. Uvella Uva	. .	. .	. .	×				
53. Stylonychia lanceolata	. .	. .	. .	×				
54. ——— mytilus	. .	. .	. .	. .	×			
55. Leucophrys patula	. .	. .	×					
56. Enchelys Pupa	. .	. .	×	. .	×	×		
57. Euplotes Charon	. .	. .	. .	×				
58. Pandorina Morum	. .	. .	. .	×				
59. Gyges granulum	. .	. .	. .	×				
60. Acineta tuberosa	Fig. 16	. .	×					
61. Stentor ceruleus	. .	. .	×					
62. Paramæcium caudatum	. .	. .	×					
63. Epistylis nutans	. .	. .	×					
64. Dileptus granulosus	Fig. 10	×	. .	. .	×			
65. Dileptus folium	Fig. 9	×						
66. Stentor Mülleri	Fig. 8	×	×	. .	×			
67. Kolpoda cucullus	Fig. 11	×	×	×	×			
68. Uvella virescens	. .	. .	×	×	×	. .	×	
69. Arcella vulgaris	Fig. 18	. .	. .	×	×			
70. Chilodon cucullulus	. .	×						
71. Oxytricha gibba	. .	×	. .	×	×	×		
72. Gonium punctatum	. .	. .	×					
73. Monas elongata	. .	×						
74. Paramæcium chrysalis	Fig. 14	×	. .	×	×	. .	×	
75. Oxytricha ambigua	. .	×						
76. Podophrys pixa	. .	. .	×					
77. Anthophysa Mülleri	Fig. 13	. .	. .	. .	. .	×		
78. Amphileptus margaritifer	. .	. .	. .	. .	×			
79. Monas glissens	. .	. .	. .	. .	×			
80. Bursaria vorticella	. .	. .	. .	. .	×			
81. Stentor niger	. .	. .	. .	×				
82. Actinophrys difformis	. .	×	×	×	×			
83. Peridinium Furca	. .	. .	. .	. .	. .	. .	×	
84. Astasia (species)	. .	. .	×					
Poriferæ.								
85. Spicula of fresh-water sponge	. .	×	×	×				
Number of ascertained species	. .	40	38	41	37	11	19	NONE.

REPORT

TO

THE DIRECTORS OF THE LONDON (WATFORD) SPRING WATER COMPANY,

ON

THE ORGANIC AND OTHER SOLID MATTERS FOUND BY MICROSCOPICAL EXAMINATION OF WATERS SUPPLIED FROM THE THAMES AND OTHER SOURCES.

BY PETER REDFERN, M.D. LOND., F.R.C.S.I., &c.,

THE waters submitted to examination were of four sorts:

1st. Waters now supplied by four of the Water Companies of the Metropolis. The specimens of each Company's water were taken from the supply-pipes before entering any house-cistern, butt, or other receptacle, except one out of seven specimens of the Lambeth Company's water from Thames Ditton.

2nd. Waters from the green sand formation in Surrey.

3rd. Aberdeen water derived from the river Dee.

4th. Watford Spring water, and the same softened.

The quantity of water submitted to examination in each case was half-a-gallon.

1st. Of the New River, West Middlesex, Thames Ditton, and Grand Junction waters.

The specimens were collected in the year 1852 by Mr. James Fry, as follows: New River water on March 29th and May 6th; West Middlesex Company's on March 30th and May 8th; Grand Junction Company's on May 7th; Lambeth Company's (Thames Ditton) on March 27th, May 1st, 6th, 15th A, 15th B, 22nd, and 29th.

When these waters were examined by the naked eye after standing for one or two days without exposure to light or heat, the New River water presented living animals to the number of fifty in each quart, together with a copious brownish deposit, easily diffused again on agitation; the West Middlesex water presented flocculi of organic matter in suspension, with a copious dark-brownish deposit, cohering in clots; the Thames Ditton water showed numerous patches of organic matter in suspension, along with animalcules in some specimens, and presented a sparing dark-brownish deposit, cohering in clots: the Grand Junction water was clear; it showed several animalcules and a sparing light-coloured and flocculent deposit. In the instances in which the deposit was clotted, this was due to the presence of filaments of fungi binding its particles together.

The deposit consisted in the New River water chiefly of living animals and plants, and of a considerable quantity of dead organic matter: in the West Middlesex water, there was a larger quantity of dead organic matter in proportion to the living organisms: in the Thames Ditton water, the deposit was mainly composed of dead organic matter and of living animals, which were the chief organisms existing in it; and the deposit in the Grand Junction water was made up of dead organic matter and of various living organisms. In none of the deposits was there earthy or mineral matter beyond a very minute proportion.

1st. *The living animals* whether found in the deposit or swimming in these waters were as follows:

(*a*) A species of worm of very repulsive appearance, found in all the four waters, and estimated at twenty in number in each quart of the New River water, whilst eleven were counted in a quart of the Grand Junction water. See page 39, fig. 19.
(*b*) Entomostraca, animals contained in shells, and visible to the naked eye, of which two species were found in the New River water, one species in the Grand Junction water, and occasional specimens in the Thames Ditton water. See page 39, figs. 20, 21, 22.
(*c*) Rotifera, or wheel animalcules, found in all the four waters; one species in the New River water, one in the West Middlesex, and two in each of the Thames Ditton and Grand Junction waters. See page 40, figs. 24, 27. (*d*) Animalcules called Tardigrada, or 'little water-bears,' found in the Thames Ditton water. See page 40, figs. 28, 29. (*e*) Polygastrica, microscopic animals with many stomachs; six species in the New River water, six in the West Middlesex, fifteen species in the Thames Ditton water, and fifteen species in the Grand Junction Company's water. See page 41.

2nd. *The living plants* were in very small number and quantity in the New River water, only one or two species being met with in each specimen; three species, one of them a Fungus, in considerable quantity, were found in the West Middlesex water; seven species existed in the Thames Ditton water, and amongst them Fungi were always found; two species, including a considerable number of filaments of Fungi, were found in the Grand Junction Company's water.

See pp. 42, 43.

3rd. *The Diatomaceæ,* living beings partaking of some of the characters of both animals and plants, were in very large quantity, and of eighteen species in the New River water; of seven species in small quantity in the West Middlesex water; of only three species in small quantity in the Thames Ditton water; and of ten species in the Grand Junction water.

4th. Dead and decaying organic matter was in large quantity in all these waters, except in the Grand Junction water, in which it was also found, though in smaller quantity. The greater part of it was without structure, but it also contained shells and cases of small animals, hairs, fragments of muscular fibre, and numerous vegetable tissues. The dead organic matter in these waters is derived partly from vegetation, partly from the numerous animalcules that live in them, and partly from the free supply of animal organic matter which they receive from the drainage of land and human habitations.

5th. Dust and soot, the usual deposit of the atmosphere of a town, always exist in these waters, and in greatest quantity in the West Middlesex and Thames Ditton waters: earthy and siliceous matters not organic are also found.

The names of the living organisms found in half-a-gallon of each of these waters are given in the accompanying Table, where × denotes the presence of the species or substance named. The number of species observed would have been much greater if the specimens submitted to examination had been larger or more numerous. For example, the characters of the Thames Ditton water are given in that Table, as they were found in a single fair average specimen of half-a-gallon, which contained 29 different species of living beings; but during the examination of seven specimens taken at different periods, no fewer than 64 distinct species were found.

General Remarks.—The four waters just named contain a considerable quantity of dead and decaying organic matter in the solid form, easily seen as a deposit with the naked eye, and recognizable as to its nature by the microscope. This organic matter, as it is continually undergoing changes, becomes dissolved in the water in considerable quantity; and were there no other evidence of this, the existence of great numbers of living animals and plants in it would furnish the most incontrovertible proofs to that effect: indeed, the Fungi, which are never absent from these waters, are plants that grow naturally on putrifying organic matters.

No other conclusion can be drawn from these facts, than that these four waters are unfit for the supply of the population of a large city. The continued administration of small quantities of decaying organic matters is undeniably prejudicial to health. Now, it must not be overlooked, that one of these waters, that supplied by the Lambeth Company from Thames Ditton, is taken from the Thames beyond the reach of the tide and of the sewage which is discharged from London, and that it is carefully filtered before being supplied by the Company; yet, in respect of organic matter, whatever be the reason, it was not found to be sensibly improved over the waters supplied by the Grand Junction and the West Middlesex Companies, though, of course, it must be much better than the water formerly supplied by the Company from the river at Lambeth. Organic matter in the solid form and in solution, as well as the smaller animals and plants, pass through the filters in large quantities; and this is not the fault of the filters, but it results from the solubility and the small size of the solid particles which require separation, and which no filter yet known will remove. A water so contaminated with organic matters, as to be unfit for use for domestic purposes, cannot be sufficiently purified by filtration or any other mechanical process.

2nd. Of the waters from the green sand formation in Surrey.

It has been proposed by the Board of Health to obtain the desired supply by collecting water from the gathering grounds near Farnham, and therefore it is important to ascertain whether such a supply possesses any prospective advantages over the present one.

Five specimens of these waters were collected by Mr. E. L. Stephens, from Bramshot, Barford Mills, Cosford House, Sweet Water Pond, and Northfleet, and were sent by him to me on May 15th, 1852, by steamer from London.

These waters contained small particles of organic matter in suspension after standing for 48 hours or more,—the particles being most numerous in the Northfleet water, and giving to it a milky or turbid appearance.

The deposit in the Bramshot water was copious, brownish, and cohering in clots; in the Barford Mills water it was considerable, brownish, and not clotted; in the Cosford House water it was scanty, brownish, and easily diffused again; in the water from Sweet Water Pond it was considerable, dark-brown, and clotted; and in the Northfleet water it was considerable, reddish-brown in colour, and light and flocculent.

These deposits contained:

1st. *Living animals.* (*a*) A species of worm in the Bramshot, Cosford House, and Northfleet waters: (*b*) Larvæ in the Bramshot, Barford Mills, and Cosford House waters: (*c*) Entomostraca, animals contained in shells, a single specimen in the Bramshot water: (*d*) Rotifera, or wheel animalcules, four species in the Bramshot water, few of one species in the Barford Mills water, and two species in each of the other three waters: (*e*) Polygastric animalcules, of more than

See page 39, fig. 19.
See page 39, figs. 20, 21, 22.
See page 40, figs. 24, 27.
See page 41.

ten species in the Bramshot water, of six species in the Barford Mills water, of nine species in the Cosford House water, of more than five species in the Sweet Water Pond water, and of eight species in the Northfleet water.

2nd. *Living plants* in small quantity, and only of seven species in the whole five waters.

See pp. 42, 43.

3rd. *Diatomaceæ*, living beings, partaking of some of the characters both of animals and of plants, in large quantity, and of no less than 33 distinct species: 19 species in large quantity in the Bramshot water; 13 species, all of small size, but in great number, in the Barford Mills water; 8 species, one of which (Meloseira varians) makes up a very large portion of the whole deposit in the Cosford House water; 9 species in very small quantity in the Sweet Water Pond water; and 13 species in small quantity in the Northfleet water.

4th. Dead and decaying organic matter without structure, amongst which are dead vegetable tissues, dead Rotifers, shells of Entomostraca, hairs of Mammals, and branched and decomposing stems or filaments.

5th. Earthy and siliceous matters and dust in small quantity in all these waters, except in the Sweet Water Pond water, in which they were in considerable quantity.

The waters from the Surrey sands were characterized as follows:

The Bramshot water, by the great number and variety of living animals and Diatomaceæ, and by the large quantity of dead organic matter, and of decomposing branched stems or filaments which it contained.

The Barford Mills water, by containing a large quantity of dead organic matter and of very small Diatomaceæ, few living animals, and a mere trace of vegetable structures.

The Cosford House water, by its deposit being almost wholly made up of one species of Diatomaceæ (Meloseira varians), the dead organic matter being in very small proportion.

The Sweet Water Pond water, by its very large proportion of dead organic matter, and small number and quantity of living animals and plants.

The Northfleet water, by its deposit being in great part composed of dead and decomposing branched stems or filaments, and containing also a great variety but a small quantity of living animals and Diatomaceæ.

Remarks.—A single quart of any of these waters, except the Cosford House water, gives a very copious deposit, containing a large quantity of dead and decaying organic matter which is continually undergoing solution in the water, and giving rise to the development of animals. As before remarked, the existence of putrescible organic matter in water completely unfits it for the supply of the population of a large town; hence no advantage whatever would be gained, on this head at least, by supplying these waters so highly impregnated with organic matter: even the

Cosford House water, which gives a smaller deposit than any other of the five waters named, and one which is composed of less objectionable matters, is unfit for the supply of a large town and for domestic purposes. These sources, therefore, must be set aside as incapable of yielding a supply of good water, on the simple ground that the waters which are collected from them are contaminated with organic matter in large quantity.

It has often been said that the water supplied from the Thames is not worse than that obtained from rivers in general, and that all river waters contain organic matters both in the dead and putrescible, and in the living state. If so, this were a strong reason for abandoning all river waters in the supply of towns, but none whatever for the continuance of the London supply from the Thames, unless it could be shown that there is no available source from which a sufficient supply of pure water can be obtained.

But in point of fact *there are towns supplied with river water that does not contain a large amount of dead and putrescible organic matter and of living animals*, as the case of the water next to be adverted to will show.

3rd. Of the Aberdeen water derived from the Dee.

This water is filtered through the sand of a natural bank as it is taken for the supply of the town, where it is delivered on the constant supply system. I examined half-a-gallon obtained by myself from the supply-pipes on May 28th, 29th, and 31st, 1852, and on several occasions in June and July of the same year, and found it as follows: when not affected by rains, it was always perfectly clear and bright, and gave so small a deposit after standing for two days that this was difficult to see until removed with the last few ounces of the fluid. At a variable period after heavy rains, the Dee water becomes turbid, and remains so for a time, which varies according to the quantity of rain which has fallen, and the distance from the spot where the supply is obtained at which the rain has been received by the river. No animal visible to the naked eye was seen in any of the specimens examined, nor is it probable that any ever exists in the water as supplied.

The deposit contained—1st, Three microscopic animals of the family Monadinæ, the largest of which measured only $\frac{1}{1200}$th of an inch in diameter; 2nd, Five species of living plants in excessively small quantity; 3rd, Ten species of Diatomaceæ, individuals having some of the characters both of animals and of plants, also in very small quantity; 4th, Dead organic matter and siliceous matters.

As regards organic matters, not one of the waters before named will bear comparison with the Dee water. In those waters the deposit from a quart is considerable, and in most of them its constant quantity is large enough to render the water turbid; whereas in the Dee water it is difficult to see that any deposit takes place from half-a-gallon on standing, whilst the water in its ordinary state is perfectly clear and bright. As regards living animals, two or three excessively small microscopic individuals are all that can be discovered in the Dee water, whilst in the before-named waters from 7 to 19 distinct species exist, and of many of these species there are myriads of individuals in the half-gallon.

The water of the river Dee, as obtained for the supply of the town of Aberdeen, is therefore unexceptionable as a water for the supply of a large town, on account of the very small quantity of organic matter and living organisms which it contains; but all the before-named waters are highly objectionable, because they contain so large a quantity of these matters. The Dee water is also very soft and agreeable to use.

The water of the neighbouring river, the Don, is decidedly objectionable on account of the large quantity of dissolved organic matter colouring it, and of the variety and number of living animals and plants it contains.

Lastly.—Of the Watford Spring water, with which it is proposed to supply the Metropolis, I examined several specimens.

When examined, this water was always found perfectly clear and bright, and on standing, it gave no deposit from half-a-gallon visible to the naked eye until the whole of the water had been removed except the last few ounces. The whole deposit from half-a-gallon was easily collected into a single drop of fluid, and was made up of crystals of carbonate of lime, particles of dust, a few vegetable fibres, such as those of flax, and a mere trace of organic matter; in other words, the deposit given by this water consisted of matters which may all be supposed to have got into it by accident, except the mineral deposit of the crystals of carbonate of lime, which came from the water itself. The conclusion I came to was, that when proper care was taken to collect the specimens, the Watford water was free from organic matter. On that ground this water is preferable even to the Dee water for the supply of a town.

Further, by the application of Dr. Clark's process for the withdrawal of the chalk it contains, the water obtained from the Watford springs becomes extremely soft and pure, and the water thus softened, when submitted to microscopical examination, was found to have lost almost the whole of the particles of the deposit observed in the unsoftened state, the precipitation of the chalk having carried down these particles and removed them almost entirely.

In a comparative experiment made by Dr. Clark and witnessed by myself, the New River, West Middlesex, Thames Ditton, Trafalgar Square, Dee, Watford Spring (hard), and Watford Spring water (softened), were equally exposed to the sun and air for more than three months. At the end of two months, microscopical examination made by myself showed that the two Watford specimens were entirely free from animals of every kind, and contained only the slightest trace of microscopic vegetable formations; the Dee water contained a few microscopic plants and animals; and in all the other waters a very copious vegetation, which was greatest in the Thames Ditton water, had occurred, and numbers of animals of different species had been formed. After the exposure had continued for more than three months, no alteration in the results were observed with the naked eye.

The water from the Watford Spring I believe to be as free from organic matter as any water can be in its natural state. After having been softened it possesses immense advantages over every other water before referred to, as now supplied, or proposed to be supplied, to the Metropolis. Indeed, the Watford Spring water possesses great clearness and brilliancy, freedom from organic matter, a low and uniform temperature, and capability of being supplied at any required degree of softness; in fact, every quality that is desirable in a water for the domestic uses of the population of a large Metropolis.

July, 1852.

Note.—The following wood-cuts represent, as seen through a microscope, some species of the Animals, Plants, Diatomaceæ, and Desmidieæ, referred to in the foregoing pages.

CHEMICAL REPORT

TO

THE DIRECTORS OF THE LONDON (WATFORD) SPRING WATER COMPANY,

ON

VARIOUS SPECIMENS OF WATER FROM CHALK SPRINGS NEAR WATFORD.

BY

THOMAS CLARK, M.D.,

Professor of Chemistry in Marischal College and University, Aberdeen;

AND

JOHN SMITH, M.D.,

Formerly Assistant in the Chemical Laboratory, and Fordyce Lecturer in the same College; now Professor of Chemistry and Experimental Physics in University College, Sydney.

WE have had the advantage of examining these waters repeatedly;—first, a specimen from the spring at Batchworth, consisting of several gallons, received by us in November 1849;—second, a farther supply from the same source, received by us about a year afterwards;—third, one of us subjected the same water to the lime-softening process in quantities of 20 gallons each, and likewise water from the spring at Redbourn, carefully observing the hardness both of the unsoftened and of the softened waters at Watford in April 1851; and a specimen of the softened water was subjected to a regular chemical analysis in Marischal College during the following month;—fourth and last, a supply of above 50 gallons from the Batchworth Spring was received by us at Marischal College in January 1852, and softened, and was analyzed, both in the unsoftened and in the softened states, with results that agreed with those we had already obtained on the same water in April 1851.

All the specimens we examined consisted of water of remarkable purity. Even among spring waters, they might be regarded as of singular clearness and brightness. The taste of them was agreeable, though tried by persons in Aberdeen accustomed to taste a very soft, and on the whole a pure water; nor are we aware of any better criterion of the agreeable taste of a water, than its palatableness to persons accustomed to drink water differing in the quantity and in the kind of its soluble contents. So free from any impurity of animal or vegetable origin did we find these waters, that although we made use of new and very delicate tests in addition to others well known, we were left in doubt whether they contained any such impurity or none; and we came to the conclusion, that when sufficient care was taken in collecting the specimen, the water was free from organic matter.

The hardness of the Batchworth water we found to be $17\frac{1}{2}$ degrees (more exactly, 17°·6 in the specimen of April 1851,—17°·7 in the specimen of January 1852); where each degree stands for as much hardness as would be produced by one grain of chalk per gallon. The hardness of this water is owing to the presence of lime; all of which, except a small fraction of a grain per gallon, exists in the water in the form of chalk, kept in solution by carbonic acid, so as to form the salt called by Chemists bicarbonate of lime. Besides lime, there is a little magnesia present, which however does not cause the water to destroy more soap, but only curdles it. Although magnesian salts when by themselves in a water cause the destruction of some soap, yet lime, when present in the considerable proportion that occurs in this water, has the remarkable property of preventing the magnesia from destroying more soap; but if three-fourths of the lime were removed, the magnesia would add to the remaining hardness to the extent of about one degree. We call this hardness in the spring water latent (or dormant). Altogether, this water is of

Sensible hardness,	17°·65;	all owing to salts of lime: 17°·60 being owing to chalk; 0°·05 to a neutral salt of lime.
Latent hardness -	0°·95;	all owing to a neutral salt of magnesia.
Total hardening contents - -	18°·60.	

A specimen from the Redbourn Spring, which proved to be a closely similar water, was found about 18 degrees (exactly 18°·20) of sensible hardness.

When we evaporated a gallon of the unsoftened Batchworth spring water and dried the residuum at 230° F., we obtained 23 grains of solid matter, left in the vessel that the evaporation was made in. On the other hand, when we evaporated, in precisely the same manner, a gallon of the softened Batchworth spring water, we obtained only 7 grains instead of 23 grains. The difference, 16 grains per gallon (2 grains per pint), is owing to chalk removed by the softening process, and comes up to the considerable quantity of 8 ton on the 8 million of gallons of water that the Company proposes to raise daily. These 8 ton of chalk (consisting of 4½ ton of quick lime and 3½ ton of carbonic acid) are kept in solution in the 8 million gallons of water by a second 3½ ton of carbonic acid. When we remove the 8 ton of chalk by the softening process, we add to the 8 million gallons of the water 4½ ton of quick lime, obtained by burning in a kiln 8 ton of chalk. This 4½ ton of quick lime joins the second 3½ ton of carbonic acid to produce a second 8 ton of chalk, which, along with the other 8 ton originally in the water, altogether 16 ton of chalk, being insoluble in water alone, falls gradually to the bottom, where, after settling, it may be seen to repose, the softened water above being perfectly bright and clear. At the end of the operation, the softening process will have removed from the water 8 ton of chalk, but it will have left nothing whatever in the water except one-10,000th part of its weight of harmless and perhaps necessary saline matter, which was all there before.

We found it easy to reduce the waters to between 2½ and 3 degrees of hardness, by the addition of a suitable proportion of lime water, or of a watery paste of hydrate of lime. In order finally to adjust the quantity of lime added to the water, the only test necessary, whether on a small or on a large scale, is a solution of nitrate of silver, which, when the lime is much in excess, gives a brownish precipitate, but when the lime is but very slightly in excess, produces only a yellowness. The aim of the operator should be to leave the clear water, when he ceases to operate, in such a state as to give only a barely perceptible yellow indication to the test. The Batchworth water, softened by lime water, fell from 17°·6 or 17°·7 of hardness to 2°·6, thus losing 15°. The same water, softened by a paste of lime, fell also to 2°·6. The Redbourn water fell from 18·° 2 to 2°·5. The sensible hardness of the softened Batchworth water was

1°·65 due to chalk,
0°·95 to neutral salts, partly of lime, partly magnesia,

2°·60 total sensible hardness.

In so soft a water none of the magnesia is in a latent state of hardness.

In order to make 100 gallons of the Thames or of the Watford water as soft as distilled water, we would have to add of soap nearly in the following proportions :

	Curd Soap.		Pale Soap.
Thames water, at 14° H. . .	$25\frac{1}{2}$ oz.	or	29 oz.
Batchworth water, softened .	$4\frac{3}{4}$,,	,,	$5\frac{1}{2}$,,

The soap thus far added would all be destroyed by the hardening matter. After such additions, each water would require the same quantity of soap as distilled water in order to produce any given effect. Thus, if 100 gallons of distilled water required 20 oz. of pale soap for a certain purpose, the Thames water would require (29 oz. + 20 oz. =) 49 oz., and the softened Watford water ($5\frac{1}{2}$ oz. + 20 oz. =) $25\frac{1}{2}$ oz.

The following is an analysis:

Analysis of the evaporated Residuum of Batchworth Spring Water.

	Grains per Gallon.		Degrees of Hardness.	
	Original.	Softened.	Original.	Softened.
Carbonate of lime	17·60	1·65	17°·60	1°·65
Nitrate of lime	0·08	0·41	0°·05	0°·25
Nitrate of magnesia	1·42	1·05	0°·95	0°·70
Nitrate of soda	—	0·09	—	—
Sulphate of soda	0·50	0·50	—	—
Chlorides of sodium and of potassium	1·30	1·30	—	—
Phosphates (precipitated by ammonia from acid solution) .	0·28	0·28	—	—
Silica	0·82	0·57	—	—
Volatile matter, including some nitric acid	1·00	1·15	—	—
Residue on evaporation . . .	23·00	7·00	18°·60	2°·60
Subtract latent hardness (magnesian salts) . . .			0°·95	0°·00
Sensible hardness			17°·65	2°·60

In respect of other qualities than the valuable one of softness, the softened spring water is clear, bright, and agreeable to the taste; it produces no fur on boiling; it may be allowed to stand in open glass vessels for any time without the slightest incrustation or powder being deposited,—bright as the purest glass, and without the slightest tendency to discolour. In such water, properly supplied, no vegetation and no insect will ever be found. Different from water that has in any degree been affected by surface drainage, it will taste like spring water naturally of an equal softness, and be unexceptionably bright when placed in glass vessels on a white table-cloth; and so pure will it show itself in the wash-hand basin or in the bath, that persons accustomed to it would soon be unable to tolerate such waters (valuable as they are in some respects) as are now supplied to the Metropolis. A few waters now supplied to towns, we know, are softer than even this very soft water, but considering the uniformity of temperature that would belong to this water at all seasons of the year, and its freedom from organic matter and from all colouring matter, we are not aware of any considerable supply made to any town that would on the whole be of superior quality. Softness, it is true, is a quality not much in demand by the inhabitants of the Metropolis generally, because, unfortunately, softness in water is a quality unknown to the great mass of them; but whensoever this softened spring water shall come to be supplied to the Metropolis, the softness of it will command a preference for it there as elsewhere; for in other towns the introduction of soft water has caused an immediate demand for such water, even by persons that possessed wells, and even when the soft water (unlike the present) was contaminated by the presence of organic matter. The proposed water, if introduced into the Metropolis, would bring to an end the just complaints of visitors from districts possessing softer or purer water than that now supplied, and could be spoken of only for its distinguished excellence.

In order to ascertain whether the softened spring water would take up any dangerous quantity of metal from leaden pipes or cisterns, we kept this water in contact with lead under precisely the same circumstances as four other waters that were not known from experience to have produced upon the consumers any ill effects from lead. The contact was continued long enough to permit a considerable action by some of the waters. Of those tried, the water that had most action on lead was the filtered water of the river Dee, as supplied to the inhabitants of Aberdeen. This water, which is about half the hardness of the softened Watford water and contains about half the saline matter, took up one-tenth of a grain of lead per gallon. The next degree of action on lead was found in the Thames water; one specimen from the West Middlesex Company's water; another from the Lambeth Company's water, derived by them from Thames Ditton. There was no perceptible difference in the action of these waters upon lead. Each took up about a half of the preceding water, or one-twentieth of a grain per gallon. Next in its action on lead was the New River water, which took up two-thirds of what the Thames water took up, or one-thirtieth of a grain per gallon. Tried in precisely the same way as the Dee, the Thames, and the New River waters, the softened Watford water showed to our tests no action on lead, although those tests would have detected in the water much less than one-hundredth of a grain per gallon.

THOS. CLARK.
JOHN SMITH.

1*st June*, 1852.