

Sir Robert Christison, Bart., the President, read the following Opening Address:—

At the commencement of this, the 89th session of the Royal Society of Edinburgh, I beg to congratulate you on the successful issue of that which has just come to an end. The number of our members has increased, in consequence both of a low proportion of deaths among us, and likewise of an increase of new members beyond the average; so that, from 326 at the same period last year, the Society has grown to 331 at the present time.

We may appeal with equal, and even more, satisfaction to the success of our late meetings; which, in the first place, were carried on a full month longer than usual before exhausting the list of communications approved by your Council as worthy of being read before you; and which, in the second place, attracted from first to last unusual attendance and interest, on the part both of ourselves and of our visitors, by reason of the variety and value of the inquiries communicated at them.

Nor, amidst these grounds of direct gratification on account of the proceedings of last year in the Royal Society itself, will it appear out of place that I further congratulate you on the great success which attended the late meeting in Edinburgh of The British Association for the Advancement of Science. Whether we consider who was the founder of this most prosperous institution—or that the Royal Society of Edinburgh and the Association were established very much for the same objects—or that our Fellows have taken an active part in its proceedings, wheresoever it may have held its meetings—or that our endeavours contributed greatly to bring it on the recent occasion to our city—or that many of us did much, or at least as much as we could, to receive our eminent guests with the cordiality due to their distinction in science—we are equally entitled to rejoice that, in respect of the number of remarkable men who were attracted hither, the excellence of the matter produced before the several sections, the interest of the excursions which the unrivalled opportunities in our neighbourhood enabled us to offer, the oft-expressed obligations of our guests for the reception they met from us and our fellow-citizens, and, I

may add, the eight days of glorious weather, upon which in Scotland much of the comfort of so great an assemblage depends—this forty-first meeting of the British Association proved in truth to be a great success.

Although the deaths in the Society have not been numerous during last year, we have nevertheless to lament the loss of several of the most distinguished among our Fellows, both ordinary and honorary. From the list of ordinary Fellows we have to strike out the names, in alphabetical order, of Dr William Anderson, Mr Charles Babbage, Mr Robert Chambers, Dr Robert Daun, Mr Alexander Keith Johnston, Dr Sheridan Muspratt, Mr Robert Russell, Sir William Scott, Dr Fraser Thomson, and Mr Moses Steven. Our honorary list no longer bears the names of Sir John Herschell, Sir William Haidinger, and Sir Roderick Impey Murchison.

Mr ROBERT RUSSELL, an eminent practical and scientific agriculturist in the county of Fife, was led to connect himself with the Society by his taste for meteorological pursuits.

Sir WILLIAM SCOTT, Baronet, of Ancrum, an enterprising country gentleman, a soldier in his youth, and afterwards for some time member of Parliament for his county, was well known for his attachment to scientific society, and for the regularity of his attendance at our meetings at a period when his avocations allowed him to reside occasionally in Edinburgh.

Dr ROBERT DAUN, Deputy Inspector-General of Army Hospitals, also a frequent attender at one time of the meetings of the Society, died in June last at a very great age [86]. He served his country with distinction in the medical service of the army throughout nearly the whole of the most momentous period, and the most critical trials, in the military history of our country. He was highly esteemed publicly for his knowledge in all departments of his profession, and his powers of organisation in his own branch of service; and he was no less prized by his friends for his acquaintance with various branches of science and literature.

Dr FRASER THOMSON, son of the Rev. Dr William Thomson of Perth, and nephew of the late eminent clergyman of Edinburgh, Dr Andrew Thomson, the first minister of St George's parish, graduated at the University of Edinburgh, where he had been a distinguished student of medicine. He settled as a medical practitioner in his native city, and for most of his life was much engrossed by the cares of an extensive practice in town and country. But, like many of his profession in our county towns, he made natural history his recreation for his short leisure hours, and applied himself eagerly to microscopical research in that department of science. In this he acquired great expertness and accuracy, and would easily have become an original inquirer, were it not that his fondness for such pursuits had not fame for its object, but simply relief from the cares and fatigues of professional life. He died, after a short illness, in the month of October, in his 65th year.

JAMES SHERIDAN MUSPRATT, a native of Dublin, was trained in the science to which he dedicated his life, under two of the greatest chemists of their day in Europe—Graham and Liebig. At the age of twenty-three he published the results of investigations carried on as a student in Liebig's laboratory on the sulphites, showing their analogy with the carbonates. Returning to Giessen three years later, he resumed his inquiries into the sulphur acids, the fruit of which was an interesting paper on the Hyposulphites, and also on Sulpho-cyanic Ether. In the interval he did good service to practical chemistry in this country by making generally known in a translation Plattner's standard work on the Blowpipe; and in 1854 he published a "Dictionary of Chemistry," which has been of great use in diffusing a knowledge of chemistry among those engaged in the practical working of chemical problems. Mr Muspratt died in the 47th year of his age.

Mr ROBERT CHAMBERS, long one of the most attached and working Fellows of the Royal Society, is one of the many instances, observed at all times in Scotland, of men raising themselves in a short time, by the sheer unaided gifts of native talent and indomitable perseverance, from an obscure position in society to a promi-

nent place in public estimation. Born, as we are told by one of his biographers, who evidently knew him and his history well, of parents respectable, but not fortunate in life, he had to struggle in his early years with difficulties. Nevertheless he was not prevented from reaping the inestimable advantages which in Edinburgh a parent of even moderate means could always command, for a son of promising parts, from an education at the High School.

Like other prolific writers, Mr Chambers began the career of authorship at a very early age. He must have been not above eighteen, when, having not long before chosen for his occupation in life that of bookseller, he determined to be publisher and author too, projecting and conducting a periodical called the "Kaleidoscope," to which he himself also contributed articles from his own pen. Soon afterwards he published "Illustrations of the Author of Waverley;" and in 1823, when only twenty years old, he added the work by which he has been longest and most familiarly known as a writer, his "Traditions of Edinburgh." Work upon work then followed in quick succession on all sorts of literary subjects, but chiefly historical and antiquarian—works which it would be out of place even to enumerate in so short a sketch as that to which this brief notice must be confined.

At last, in conjunction with his elder brother, Mr William Chambers, was begun in 1832 the now famous "Chambers' Edinburgh Journal,"—the first idea, and as such a great invention, of a weekly periodical devoted to short productions, original, as well as critical, on nearly all literary and also some scientific subjects, suited for the information, as well as for the purse, not alone of the educated classes ordinarily so called, but likewise for the educated in the humbler walks of life. This undertaking met soon with extraordinary success—in so much, indeed, that it became the parent of many others identical or similar in their aims, and not a few of them not less prosperous than that of the two brothers Chambers.

While adhering steadily to his literary tastes, and giving forth in various works the results of his literary labours, Mr R. Chambers' attention was turned to a totally different object of study, which in all probability he first followed as a diversion, or distraction

from the severity of professional toil. This was geology, which in the end captivated him, and first made him an active, energetic member of this Society. Cultivating his new pursuit with his inherent fervour unabated, he soon became an original inquirer in this fascinating branch of natural science. Besides making himself acquainted with the rock structure of many parts of his own country, he visited as a geologist Switzerland, Norway, Sweden, Iceland, the Faroe Islands, and parts of Canada and the United States. Few geological amateurs, engaged in a profession usually so engrossing as that of Robert Chambers, have acquired such intimate knowledge of geology. Many of us can recall the interest of his discussion of geological questions at our ordinary meetings; and his "Ancient Sea Margins" will long be known as one of the earliest, most exact, and most lively descriptions of that particular branch of his favourite study.

Mr Chambers was distinguished, alike in his public appearances, as in social intercourse, by a great fund of information on most diversified topics of interest in literature and science, by his caution and politeness in criticism, and by his courteous kindness in every relation of life. In the last respect he will be long missed by a numerous circle of attached friends, many of whom were his fellow-members of the Royal Society of Edinburgh. In March 1871, after a tedious and enfeebling illness, borne with singular patience, he died in the 69th year of his age.

I turn next to another no less serious loss sustained during the past year by science and this Society in the death of Mr ALEXANDER KEITH JOHNSTON. Mr Keith Johnston at first intended to join the medical profession; but, at an early age, he betook himself to the art of engraving, which again led him to the study of geography; and from that time geography became his ruling pursuit, and the object of his professional life.

In 1830, having had occasion, during a pedestrian trip in the Highlands, to remark the inaccuracy of the maps of Scotland, he published an improved collection in a Guide Book. At the same time, to facilitate the development of his geographical enterprises, he joined the firm of his two brothers, Sir William and Thomas Johnston, which had been established in this city some years

before for carrying on the business of engraving and printing, in which they have been long famous among the skilful engravers of Edinburgh. In his thirty-ninth year he attracted the regard of scientific geographers at large by the publication of his "National Atlas," and still more, five years later, by his "Atlas of Physical Geography." For the task he had thus set himself he had been thoroughly prepared by assiduous study of the best works in the various languages of Europe, by frequent visits to many European countries, and by acquaintance and personal intercourse with the greatest continental geographers and travellers. Not long afterwards Mr Keith Johnston brought out in succession a "Dictionary of Geography," a "Military Atlas" for Alison's "History of Europe," the "Royal Atlas of Modern Geography," and subsequently a variety of cheap atlases for the use of schools. By these productions he raised himself to a position in which he had no superior rival as a geographer in this country; and his merit in this respect received the stamp of the Royal Geographical Society of London in the last year of his life by the award of the Geographical Victoria Medal.

But Mr Johnston took also great interest in almost every branch of physical research, with many of which he had no mean acquaintance, and whose cultivation in this city he seized every opportunity to encourage and promote. Among other obligations to him, we are greatly indebted for the foundation of "The Meteorological Society" of Scotland,—an institution which, under the able direction of its present Secretary, promises important results, certain, indeed, to be realised if the Society receive due public support in the line of inquiry in which it has already been for some years successfully engaged. It is also known to me that the city and University are mainly indebted to him for the early foundation of the Chair of Geology, through the munificence of his friend the late Sir Roderick Murchison. At the direct instance of Mr Johnston, and through the weight which his genuine love of science commanded with many men of influence, Sir Roderick was induced to alter his intentions, from a "post-obit" foundation, to an immediate gift, of the Chair, in conjunction with a Royal Foundation and additional endowment.

In such proceedings as these Mr Johnston did good with no

ulterior view, and from no love of being what our neighbours across the channel aptly call a “grand faiseur.” Hence we scarcely know how much we owe to him. His extensive acquaintance with the upper ranks of what it has become the custom to call the “citizen class” in Edinburgh, enabled him often quietly to direct public opinion in the nice exercise of scientific, literary, and professional patronage, when sound direction was greatly needed; and his acknowledged prudence, probity, impartiality, and knowledge of men, never failed to guide himself soundly in such conjunctures.

Throughout his whole life he was faithful and fruitful in his calling, and no less a sincere and active Christian. Seldom has there been a more affable, agreeable, and profitable companion in social life in all its phases.

Although far from being a young man at his death,—for he died in his 67th year,—we have to lament that he was struck down while in full possession of his powerful intellect, and enjoying shortly before a vigour which promised long continuance of his useful labours.

WILHELM RITTER VON HAIDINGER, one of our Honorary Fellows, was a favourite pupil of Mohs; who, during great part of the first half of this century, was celebrated as one of the foremost mineralogists of his day in Europe, and as the able Professor of Mineralogy in the University of Vienna. While yet a young man, William Haidinger possessed an extraordinary extent and accuracy of knowledge of minerals. On account of his talents as a descriptive mineralogist, he came to Edinburgh, about the year 1824, to arrange and catalogue the splendid mineralogical collection of a former curator of our Society, Mr Thomas Allan, banker in this city,—a collection unrivalled, for extent and careful costly selection, among the private mineralogical museums of Europe. In discharging this duty Mr Haidinger was enabled to establish several species as new to science; which he investigated and communicated to our meetings in conjunction with the late Edward Turner, the chemist, at the time lecturer here, and soon afterwards first Professor of Chemistry in University College, London. Haidinger took the descriptive, Turner the analytical, part of these inquiries; and, in both respects, their papers are models of

mineralogical investigation. I was at this time intimately acquainted with Haidinger, and could well appreciate his mineralogical facility and acuteness, his varied knowledge of natural history and physical science, and his remarkable command of languages,—so that, for example, in our own tongue, he could tell a jocular story, make a pun, and extemporise a clever couplet,—which I take to be about the severest of all tests of a man's familiarity with a foreign language.

No one who knew him at that time could fail to see that Haidinger would one day become a man of mark among the mineralogists of his own land, to which he returned soon after completing his labours in Mr Allan's museum. He then travelled for some time with Mr Allan's son, Robert, who died a few years ago a Fellow of this Society; and the main object of the travellers was the pursuit of mineralogy. Ere long Mohs died, and Haidinger succeeded him in his University Chair. His office put him naturally at the head of all relative Government undertakings, which in their turn brought him promotion, till at length he filled the highest office in his profession, that of Director of the Mineralogical and Geological Survey of Austria. For his many scientific and practical services to his country he received from his sovereign the honour of knighthood a few years before his death, which took place last April in, as I understand, the 71st year of his age.

Coming nearer home, I have next to deal with the scientific life of another lost Honorary Fellow of the highest rank in Physical Philosophy, Sir RODERICK IMPEY MURCHISON, Baronet. But though very willing, and not altogether unable, to do justice to his remarkable labours in his science, I felt that I should be acting with injustice to his memory, and to the claims of a far superior biographer and eulogist, if I did not transfer from myself to Professor Geikie the pleasing task of recalling to our recollection the main points in the life and the work of his patron and friend. The following summary is accordingly the tribute which Professor Geikie has kindly enabled the Society to pay to the fame of Sir Roderick Murchison:—

“Among our recent losses there is none which we have more reason to deplore than his. The name of Sir Roderick Murchison

has been a household word in geology for nearly half a century, not in Britain only, but also over all the world. While we share in the wide regret at the injury which the general cause of science sustained by his removal, we add also the sadness which arises from the recollection of the relation which he bore to the progress of geology in Scotland, and from what he has recently done for the advancement of its study in the University of this city.

“Born in 1792 at Tay⁹adale, in Ross-shire, he was educated for the military profession, and served during part of the Peninsular War. But on the arrival of peace in 1815, finding that the army no longer opened up the same prospect of activity for which he longed, he gave up his commission, married, and settled in England. The succeeding part of his life, prior to 1824, he used to speak of as his “Fox-hunting period,” when he threw himself with all the ardour of his nature into the field sports of a country residence. Part of that period, however, he spent abroad, making, with his wife, tours in search of picture galleries and old art, and keeping an elaborate diary, with criticisms on the character of the fine arts in each tour or collection visited. It was by a kind of happy accident that his energies were at last directed into the channel of science,—the merit of which change was due partly to his wife’s taste for natural history, and partly to the friendly counsel of Sir Humphrey Davy. He joined the Geological Society of London, and soon became one of its most enthusiastic members. From that time forward his love for geology, and his activity in its pursuit, never waned. He travelled over every part of Britain, and year after year he resorted to the Continent, traversing it in detail from the Alps to Scandinavia, and from the coasts of France to the far bounds of the Ural Mountains. As the result of these journeys, there came from his pen more than a hundred memoirs, besides two separate and classical works on ‘The Silurian System,’ and on ‘Russia.’

“Sir Roderick was essentially a geologist, and he chose one special branch as his own domain. Perhaps no man ever had the same power,—which seemed sometimes almost an intuition,—of seizing the dominant features of the geographical and palæontological details of a district. With a keen eye to detect the characters as they rose before him, and a faculty of rapidly appreciating their

significance, he could, as it were, read off the geology of a country after a few traverses only, when most men would have been puzzling over their first section. This was the secret of his broad generalisations regarding the geological structure of a large part of Europe,—generalisations which, though of course requiring to be corrected and modified by subsequent more detailed investigations, still remain true in the main, and still astound by their marvellous grasp and suggestiveness. The leading idea of his scientific life was to establish the order of succession among rocks, and through that order to show the successive stages in the history of life on our globe. With the more speculative parts of geology he meddled little; nor did he ever travel outside the bounds of his own science. He early recognised the limits within which his powers could find the fullest and most free development, and he was seldom found making even a short excursion beyond them.

“The special part of his work on which his chief title to fame rests is undoubtedly his establishment of ‘The Silurian System.’ Before his time, the early chapters of the history of life on our globe had been but dimly deciphered. William Smith had thrown a new flood of light upon that history by showing the order of succession among the secondary rocks of England, and had done more than any other man to dispel the prejudices with which the doctrines of Werner seemed naturally to fill the mind. But the rocks older than secondary, to which Werner had given the name of ‘Transition,’ remained still in deep Wernerian darkness. Sir Roderick Murchison saw that it might be possible to bring order and light out of these rocks, even as had been done with those of more recent origin; and that a double interest would attach to them if, as he supposed, they should reveal to us the first beginnings of life upon our globe. Choosing a part of the broken land of England where the rocks are well exposed, he set himself to unravel their order of succession. Patiently year after year he laboured at his self-appointed task, communicating his results sometimes in writing to his friends, sometimes in the form of a short paper to the Geological Society of London, until at last, in 1838, he gathered up the whole into his great work, ‘The Silurian System.’ In that book the early chapters of the history of life on the earth were first unfolded, and a system of classification was

chosen with such skill that it has been found applicable, with minor modifications, even in the most distant quarters of the globe.

“Round this early work all his after-labours seemed to range themselves by a natural sequence. His choice had led him into the most ancient fossiliferous rocks, and to that first love he remained true. Whether in the glades of Shropshire, or the glens of his own Highlands, among the fjelds and fjords of Norway, or in the wilds of the Urals, it was with the Palæozoic formations that he mainly busied himself. They were to him a kind of patrimony which had claims on his constant supervision. With his friend Sedgwick he unravelled the structure of the middle Palæozoic rocks of Devonshire, and with Keyserling and De Verneuil he showed the true relations of the upper Palæozoic rocks of Russia. The Silurian, Devonian, and Permian systems, representing each a vast cycle in the history of our earth as a habitable globe, received in this way from him their first clear elucidation, and the very names by which they are now universally known.

“But if we seek to measure the influence which Sir Roderick Murchison exercised on the progress of the science of the time merely by the original work which he himself accomplished, we should fail duly to appreciate the measure and the power of that influence, and the extent of the loss which his death has caused. Fortunate in the possession of wealth and high social position, he was enabled to act as a constant friend and guardian to the cause of science. He moved about as one of the representative scientific men of his day. To no man more than to him do we owe the public recognition of the claims of scientific culture in this country. For he not only stood out as the acknowledged chief in his own domain, but had also the faculty of gathering round him men of all sciences, among whom his kindliness of nature, his courteous dignity of manners, his tact and knowledge of the world, and his wide range of social connections marked him out as spokesman and leader. Nowhere were these features of his character and influence more conspicuous than in his conduct of the affairs of the Geographical Society, of which he was for many years the very life and soul, and which owes in large measure to him the stimulus it has given to geographical science.

“Here in his own native country, and more especially here in

Edinburgh, we have peculiar cause to mourn the loss of such a man. Though his residence from boyhood had been chiefly in London, he never to the last relinquished his enthusiastic regard for the land of his birth. He never lost an opportunity of boasting that he was a Scot. During the last ten years of his life he made frequent and protracted tours in the Highlands; and, in unravelling their complicated geological structure, he accomplished one of the most brilliant generalisations of his long and illustrious scientific career. There is something touching in the reflection that, after having travelled and toiled all over Europe, gaining the highest position and rewards which a scientific man can attain, he should at last, ripe in years and in honours, have come back to his own Highlands, and there completed his life-work by bringing into order the chaos of the primary rocks, and laying such an impress on Scottish geology as had never been laid before by any single observer. For these and other researches he received from this Society the first Brisbane Medal—an honour conferred on him at the Aberdeen meeting of the British Association, and of which he often spoke as one that gave him the deepest gratification. He used to boast, too, of being an honorary Fellow of this Society, and to quote a remark made to him by the late Robert Brown, that his election into the list of our honorary Fellows was one of the highest marks of distinction he could receive. His kindly interest in our prosperity was often expressed; and we have a token of it in the presentation to us of his bust by Weekes, which this evening is formally delivered to the Society.

“Of the closing acts of his life, there is one which cannot be mentioned without peculiar pride—the institution of a Chair of Geology and Mineralogy in the University of Edinburgh. He intended to found this Chair by bequest; but on the retirement of Dr Allman from the Chair of Natural History, he determined to do in his lifetime what would otherwise have been accomplished not till after his death. He gave to the University a sum of £6000; and the Crown having consented to add an annual grant of £200, the Chair was founded in the spring of the present year. Sir Roderick has not lived to witness the first beginnings of the tuition which he had started. But long after the memory of his personal character shall fade, men will remember the work which

he did; they will recognise the impetus his researches have given to geology all over the world; and let us hope also they will see in the Chair he has founded the starting-point of a new and active school of Scottish geology.”

I have left to the last in this biographical sketch of our lately deceased Fellows two of the most eminent men of British science in their day—HERSCHEL and BABBAGE. For as I could not pretend to do justice to the lives of men whose pursuits, in the highest range of physical science, were so far removed from my own, I think it right to keep quite apart the following eulogium, the preparation of which my university colleague, Professor Tait, has kindly allowed me to impose on him, and which I will give in his own words:—

“Of Sir John F. W. Herschel and Charles Babbage, who may be fitly mentioned together, it is not necessary that much should be said, as their contributions to science cannot fail to be set forth at length in the Proceedings of other Societies, with which they were more connected than with our own. Intimate friends during their undergraduate career at Cambridge, they joined us as ordinary Fellows shortly after taking their degrees, and when they were just commencing, along with the late Dean Peacock, what all must consider, in spite of their other grand contributions to science, the greatest work of their lives—the restoration of mathematical science in Britain. It is impossible even now to overestimate the value of this service. Few know to what a state of ignorance we had fallen at the time when Lagrange, Laplace, Fourier, Cauchy, Poisson, and Gauss, and many others abroad, were advancing with breathless rapidity in the track, neglected by us, of James Bernoulli and Euler. Partly from a mistaken notion that they were honouring Newton by adhering to his published methods, partly owing to the British dislike to men and things foreign, which at this time was pushed, perhaps not unnaturally, to extreme lengths in all matters, and partly in consequence of our long state of war with France, our mathematicians had never even learned those unpublished methods by which Newton made his discoveries, which, as soon as they were to some extent divined

abroad, were at once estimated at their true value, and pursued with zeal and genius.*

“Little by little, first by translating Lacroix’s elementary treatise on the differential and integral calculus, and by thus introducing, in face of determined opposition, the notation of differential coefficients into Cambridge, so as for the first time to enable her mathematicians to understand a foreign treatise; secondly, by publishing an excellent collection of examples; and thirdly, by their separate original treatises on different special parts of analysis, they put this country on a level with France and Germany, so far at least as opportunities of progress are concerned. It is to them mainly that we owe, not merely our modern British school of mathematicians, which is now certainly second to none in the world, but even the very possibility of the existence in this country of such great departed masters as Boole and Hamilton.

“Herschel’s ‘Treatise on Finite Differences,’ which appeared as a supplement to the translation of Lacroix, is one of the most charming mathematical works ever written, everywhere showing

* Professor Tait has urged me to make known a reminiscence of my youth that at the time here referred to there were in Edinburgh, and in this Society, no fewer than three mathematical amateurs, who, though they never made themselves publicly felt as such, in some measure saved this corner of the land from the censure dealt in the text. These were Sir William Miller, Baronet, of Glenlee, better known as Lord Glenlee of the Scottish bench; William Archibald Cadell, of the family of Cadell of Grange, who finished his earthly career but a few years ago; and my own father, Professor of Latin in our University. Lord Glenlee, a man of very retiring habits and disposition, was usually called the first amateur mathematician in Scotland. Mr Cadell, also a man of great reserve and shyness, nevertheless, in order to carry out his admiration of the modern continental mathematics, contrived to obtain, during the very hottest of our struggles with France, from that generally unyielding potentate, the First Napoleon, permission, through the influence of one of the great mathematicians of Paris, to repair to the French capital, to dwell there for seven years, and to return unhindered to Scotland, at a period when no other Briton was known to have put his foot on French soil without being made a *detenu*. My father, during the last ten years of his life, which ended in 1820, betook himself, as his idea of relaxation from routine professional life, to the differential calculus, and to Newton, Bernoulli, Euler, Lagrange, Laplace, Lacroix, &c., whose works were always at hand when not in his hands. As he made a vigorous attempt to indoctrinate me at a very early age in his favourite pursuits, I know well what these were, and what he knew of the kindred spirits Glenlee and Cadell.

power and originality, as well as elegance. In all these respects it far surpasses his subsequent mathematical writings, excellent as are many of them; for instance his celebrated treatises on 'Light' and on 'Sound' in the 'Encyclopædia Metropolitana.' The appendix to Lacroix which was written by Babbage, was devoted to the 'calculus of functions,' a strangely weird branch of analysis, which remains even now much as Babbage left it. That in this direction there is a splendid field open for the inquirer, is evident to any one who consults Babbage's papers on it; and it is wonderful that it has not been greatly developed of late years, when so many mathematicians, especially at home, have been found to apply themselves almost exclusively to those branches of the science which seem the least likely ever to have useful applications.

"In their after-life the careers of these great workers and thinkers led them widely apart. Herschel devoted himself mainly to astronomy, but also to chemistry, photography, and occasionally to mathematics. His astronomical work is all of the very highest class, whether it consisted in his seclusion, for several of the best years of his life, at the Cape of Good Hope in the close observation of the stars and nebulae of the Southern Hemisphere; or in first writing, and then, as edition after edition was called for, extending and improving his splendid semi-popular work, the 'Outlines of Astronomy,' which none, even of men of science, can read without deriving from it at once pleasure and profit.

"Babbage, on the other hand, applied himself mainly to machinery and manufactures. His so-called 'Ninth Bridgewater Treatise' was pre-eminent even among the best of that singular series; his 'Economy of Machines and Manufactures' is still a wonderfully suggestive work; and his 'Mechanical Notation' supplies us with an insight into the kinematics of all possible combinations of machinery, which none can have any conception of without making it a special subject of study. He was led to its invention by his celebrated attempts to achieve the construction of a difference-engine, and even of an analytical engine—machines totally unintelligible, in their conception, to the majority even of those who are capable of understanding the nature of the work for which they were designed. Enough was constructed, though it was a very small part, of the first of these engines to show not only that

the device was completely successful, but also to exhibit the extraordinary talent of the inventor in such a light as to convince scientific men that in his hands the astounding problem of constructing the second was capable of solution. A paltry economy of the Treasury prevented the completion of the first engine, and made it obvious to Babbage that there was no hope of assistance from Government to construct the second. Yet it has been allowed by the best authorities that the money spent on the finished portion of the difference-engine was far more than repaid to the country by the extraordinary improvement in tools of every kind, which was required for the new engine, and was at once supplied by the fertile, inventive brain of Babbage as the work proceeded.

"No one can read the obviously true story of this miserable affair, as it appears in the strange autobiography of Babbage—his 'Passages from the Life of a Philosopher'—without a blush for the short-sightedness of British rulers. Had Babbage been a Frenchman or Russian, had he even belonged to the then poor kingdom of Prussia, do we not all feel assured that these grand conceptions of his would long ere now have been realised as powerful agents in the working world, instead of lying dormant, in mouldering, worm-eaten plans and sections.

"Strange the contrast between the careers of these early friends! They began, indeed, by a grand joint success, for which alone their memory will always be justly cherished. But while the one, encouraged, yet never unduly elated, by success, steadily at work, though not of late years brilliantly, ended a long and happy life, every day of which had added its share to his scientific services; the other, enraged by the petty persecutions of men unable to understand scientific merit, or even its mere pecuniary value, spending lavishly from his private fortune to be enabled to leave to some possibly enlightened posterity a complete record of the working details for the construction of his splendid inventions, was never understood by his countrymen.

"But so it has ever been in this country. Herschel's father was a German; so of course we could appreciate him. Babbage was an Englishman; the only person who took the trouble to understand his invention was a foreigner, the skilful mathematician Menabrea, ex-minister of Victor Emmanuel."

Observations on the Fresh Waters of Scotland.

Looking around me for some general theme suitable for the subject of this introductory address, I became oppressed with the persuasion, that no such subject, worthy of your acceptance, had been left unexhausted by the able men who have lately had to treat of scientific topics of a general nature in circumstances akin to my own on the present occasion. I therefore thought I might trust to your indulgence, and substitute for a general address a notice of some inquiries, which have been carried on from time to time during my late occasional autumn holidays, and which promise results of some interest, illustrating the hydrography of the fresh waters of Scotland. These inquiries have in several respects been pushed not so far as to satisfy me completely. But as I may not be able to carry them through according to my present design, and I hope that others may be led to interest themselves in also pursuing them, I beg to submit the results to the Society, such as they are.

The topics I propose now to bring forward,—which are rather diverse in nature, yet not altogether unconnected with one another,—are three in number,—*First*, The composition of the water of certain lakes and their leading streams in Scotland, and the changes their waters undergo in the streams which the lakes feed; *Secondly*, The temperature of these lakes at various depths; and, *Thirdly*, The action of their waters upon lead.

I shall commence by recalling shortly the geological structure of our country, by which in a great measure the nature of its waters is regulated.

In the primitive formations which constitute the “Scottish Highlands” of ordinary speech,—for in correct language many parts of the so-called “Lowlands” are as well entitled to the other name,—we find that the mountain summits are either pointed or rounded, but seldom table-topped; that their spurs are commonly rather sharply ridged; that their surface abounds in precipices, crags, loose blocks, rocks, and stones; and that the valleys between them, except in the course of our largest rivers, are narrow, gravelly, or rocky, thinly covered with vegetative soil, and consequently little fit for plough cultivation. Not infrequently, however, the spurs or buttresses, instead of being ridgy, are broad and flat,

smoothly covered with fine heather, the favourite breeding-place for grouse, and tolerably dry, except where small patches of peaty bog show themselves here and there. This structure is often well exemplified among the mountains of Glen-Shee. Again, when the spurs of a mountain are ridgy, the ridges are sometimes separated from one another by an upland valley, often very grassy, especially towards its head or "corrie," but likewise apt in many places to be boggy, and there abounding in peat, and in denuding cuts which expose the peat to atmospheric influences. Good examples of such upland valleys are to be seen on the Cobbler, and on its higher northern neighbour Ben-Arnen, where they face Arrochar eastward, and also on Ben-Lomond northward from its peak. Exposed peat constitutes on the whole no great proportion of the surface of most mountains in the Highlands.

It follows from this structure, that in most districts of the Highlands rain and melted snow find little to dissolve in descending the mountain sides; and their steepness causes the streams to tarry a very short time in their descent, and to drain off quickly the excess of water in flood-time. All these circumstances combine to render the streams and lakes of the Highlands uncommonly pure in dry weather, and not materially less so even in heavy floods. Among the granite ranges, such as in the Goat-Fell district of Arran, the streams, such as the Rosa and Sannox, are beautifully clear and colourless in the highest floods. The temporary water-falls which then streak the mountain slopes, present to the eye the purest whiteness; and on filling a glass tumbler from a stream, the water, after the instant subsidence of a few coarse particles of granite sand, is seen to be perfectly transparent and free from colour. In the mica-slate districts of the near Grampians the streams are equally pure in dry weather. But after rains they are visibly brownish, yet so slightly that in a common water-bottle on a dinner-table the colour may readily escape notice.

During last autumn I had frequent opportunities of examining, in various circumstances, the water of one of these mica-slate streamlets, which is used for supplying a villa near Loch-Goil-head. The stream descends the steep eastern slope of "The Cruach," a hill which land-locks the upper part of Loch Goil on its west shore at a point about a mile and a half from the Head. Although only

2000 feet high, “The Cruach” presents an imposing, rugged, conical sky-line to one entering Loch Goil from Loch Long. The east face, precipitous at the summit, is entirely grassy lower down, unless where broken by other precipices, out-cropping rocks, or stream-courses, also always rocky. There is little peat to be seen anywhere, and no agriculture. From various trials around Loch Goil and Loch Lomond I am satisfied that this streamlet is a fair type, both in its ordinary state and in its occasional variations, of most of the streams which tumble into these sheets of water from the mica-slate mountains around them.

When I examined this water in the end of September, after ten days of perfectly dry weather, following a heavy twelve-hours’ rain two days earlier, it was beautifully clear and sparkling. In the first place, it was entirely free from colour. The absence of colour was tested conveniently and delicately by means of a glass tube 16 inches long and six-tenths of an inch in diameter, which is nearly filled with the water to be examined, and is held over, but not touching, a sheet of white paper in a bright light. For security, a very fine colourless spring water was always kept at hand for comparison in another tube. The slightest coloration is thus seen by looking perpendicularly down the tube. Or it may be equally recognised by looking at the surface of the water obliquely through the upper part of the tube from a distance of 18 inches or 2 feet; for the colour is thrown up by the paper, and concentrated, as it were, on the surface of the water, though the long subjacent column, as seen through the glass, appears colourless. Very few waters, except that of springs, withstand altogether this test of the presence of colour.* Mr Dewar has suggested that it admits of being made a water-chromometer, by employing for comparison,—distilled water being used for fixing the zero point,—a solution of some invariable strength of a permanent per-oxide salt of iron, such as the acetate, and diluting the solution to uniformity of depth of colour with the water to be compared. The amount of dilution would denote the degree of coloration relatively to a fixed standard.

In the second place, this water contained a very small propor-

* This method, devised for the occasion, I have since found to be a mere variety, but more convenient, of one proposed some years ago by Dr Letheby, and adopted by the late Professor Miller.

tion of saline matter. In by far the greater number of streams and lakes in Scotland, whether Highland or Lowland, the salts met with are the same, viz., carbonates and sulphates of the three bases, lime, magnesia, and soda, and the chloride of their metalloids, calcium, magnesium, and sodium. Of these the chlorides are usually most abundant, the sulphates least so; and of the bases, lime is commonly predominant, magnesia the contrary. But frequently in the Highland streams the proportion of all is so small that most of the ordinary liquid tests scarcely affect them. In the water now under consideration, for example, magnesia, among the bases, was not indicated by the alkaline phosphate of ammonia; nor was sulphuric acid, among the acids, by nitrate of baryta; even lime was doubtfully indicated by oxalate of ammonia; chlorine, too, was scarcely indicated by nitrate of silver in a small test-glass, and required a quantity amounting to six or seven ounces to yield an undoubted faint mist; and permanganate of potash did not denote organic matter except faintly. Acetate of lead, however, by acting on both combined carbonic acid and organic matter, showed a haze even in a small quantity of the water; and so did tincture of potash-soap, by virtue of the decomposing influence on it of earthy carbonates and free carbonic acid together.

After frequent trials I am inclined to think, that for practical purposes, when organic matter does not require to be taken into account, we seldom need any other test for ascertaining the relative purity and usefulness of these waters than the late Professor Clark's soap-test. In the present instance this denoted in several trials only 1.04 degrees of hardness, which is equivalent to that much of carbonate of lime in an imperial gallon of 70,000 grains of water. From frequent observation of the effects of this and other liquid tests, I feel assured that the total solid contents could not have been more than a 25,000th of the water, and was probably nearer a 30,000th.

In the third place, this composition, viz., little saline and extremely little organic matter, would lead to the expectation that the water will corrode lead. And so it does, but not powerfully. A thin plate of lead, with $4\frac{1}{2}$ square inches of surface, weighing 437 grains, was suspended by a lead rod in this water. In twenty-eight

days it lost only 0·42 grain in weight, and crystals of carbonate of lead were deposited scantily. In circumstances exactly the same, distilled water will form carbonate of lead in abundance, and the loss of lead is 3·4 grains, or eight times as much.

In times of flood the condition of the water in such streamlets necessarily undergoes change. But the difference is not so great as might naturally be expected. In the night of 19th September last and subsequent morning rain fell steadily at Loch Goil, and heavily for twelve hours; and, consequently, in the forenoon of the 20th the streamlet described above was considerably flooded. The water, seen in bulk, was somewhat brownish; it was even faintly brownish in a dining-room water-bottle; and in a 16-inch glass tube it appeared yellowish. Nevertheless, it looked well enough in a glass tumbler, and it was not in the slightest degree turbid. Its purity, apart from its colour, was very great. No liquid test for inorganic salts but one,—not oxalate of ammonia, not nitrate of silver, not even acetate of lead, had any visible effect. The soap-test alone exerted any manifest action; and this indicated only 0·8 degrees of hardness, which is equivalent to little more than an 80,000th of carbonate of lime in the water. In correspondence with this condition, lead underwent rapid corrosion in it. A plate, an inch and a half square, lost in twenty-eight days 3·09 grains in weight, or about $\frac{1}{4}$ ths of the loss in distilled water in the same time; and crystals of carbonate of lead were formed in abundance.

I examined the same stream on a previous occasion after a furious tempest and rain-flood on the 24th August last. Much rain had fallen at Loch Goil previously for several days. But on the 24th it fell in torrents, and for half-an-hour that forenoon like a tropical deluge. During this period a great extent of grassy turf was torn off in the upper part of the stream, probably by a water-spout. In a few minutes the streamlet, already in high flood, became a muddy tumultuous torrent in which no man could have stood or lived; swiftly its muddy waters spread out over the salt water of Loch Goil; and then meeting similar floods first at its own side, and afterwards from the opposite shore, the united muddy torrents covered the whole upper reach of the loch in less than half-an-hour to the extent of two miles in length, and three-quarters

of a mile in average breadth. A rainy day followed, and then four days of uninterrupted dry weather, during which the stream returned nearly to the same state in volume and appearance as after the moderate flood already described. There was this difference, however, even in its composition; nitrate of silver feebly indicated chlorides, and acetate of lead also feebly indicated carbonates. The difference was probably owing to a material difference in the direction and force of the wind. On the former occasion the wind blew from the north-east, with no great violence, over about 90 miles of land; but on the latter occasion it blew with fury from west to south-west over Loch Fyne at distances varying from 18 to 15 miles only. In the latter case sea-spray must have been swept up into the air and carried far by the storm. In the former less would be raised into the atmosphere, and much would be deposited again in passing over 90 miles of land. In 1845 I found chlorides distinctly indicated by a white cloudiness, when nitrate of silver was added to rain-water collected on the top of Goat-Fell in Arran, towards the close of a violent four days' south-westerly gale, attended with frequent heavy rain, the sea in the direction of the wind being 12 miles distant, and 2800 feet below.

The facts now stated, which I have often corroborated by less minute observation of other streams in the mica-slate district of Loch Long, Loch Goil, and Loch Lomond, will convey some idea of the constitution of these waters in three conditions, viz., after high floods, moderate floods, and dry weather. To complete the series, it is an object of interest to add their condition after very prolonged drought. In that case the streamlets, except those fed by small upland "tarns," will come at last to convey only the water proceeding from springs; and many not so supplied will dry up altogether. For the composition of those which continue to run we may look to the springs themselves which feed them, because in their then very low state, running chiefly over rocks and stones, their waters will contract little additional impregnation in their course downwards. I have examined several springs in the mica-slate district under consideration. They have generally presented rather more saline constituents than the streams in their ordinary state, and invariably no colour appreciable by any of the ocular

tests I have used as described above. Sometimes their salts are scanty; but always they are quite colourless. Their solids appear to vary from a 16,000th to a 21,000th; and chlorides and lime-salts are, for the most part, indicated by their proper liquid tests rather more distinctly than in the general run of stream waters in their ordinary state of fulness. Several small springs high on the hill slopes have yielded these results. Similar in that respect is a copious spring in Glen Beg, more familiarly known by the name of Hell's Glen, about three miles from Loch-Goil-head in the narrow pass to St Catherine's on Loch Fyne. This spring, which gushes in force near the highway and close to the valley stream, is at all times beautifully limpid, and seems to be little affected in volume by droughts or floods. Its temperature is 44° when the air is 64° and more, though its site is not much over 300 feet above the sea-level. Its water is perfectly colourless, but contains rather more chlorides and earthy salts than the waters of the streams in their ordinary condition. Another more remarkable spring of great volume issues from the south flank of the Cobbler, about 1500 feet perpendicular above the bottom of Glen Croe, and leaping from rock to rock, joins the Croe about half-way up the glen. In the very dry season of 1870, its course was the only one which showed any water among the many which score the steep slope of the mountain where it overlooks the glen from the north. I found the water last autumn, after ten days of complete drought, to be perfectly colourless, and to be so free from saline matter as to be barely affected even by the delicate liquid tests for chlorine and for lime.

As the various streams now described are the feeders of the fresh-water lakes, which abound in the mica-slate districts, the composition of the water of the lakes must be the same with that of the average water of the streams. The small upland "tarns" are peaty, owing to the peat which paves and surrounds them. But the great low-lying lakes present very little solid matter of any kind in their waters; their scanty salts consist of chlorides, carbonates, and sulphates, the bases being lime, soda, and magnesia; and the organic colouring matter is so small as to be discoverable by delicate tests only. In all instances, however, our purest lake

waters in a mica-slate country are slightly — very slightly coloured.

The water of Loch Katrine is a well-known and characteristic example. Some years before the proposal was first entertained to use it for supplying Glasgow, I found it to contain only a 40,000th of solids. When compared with a fine spring water, however, it now presents in a 16-inch glass tube an appreciable, yet very faint, yellowness. In hardness it indicates only 0·65 by the soap-test, or the equivalent of a 108,000th of carbonate of lime. In correspondence with this great purity it acts powerfully on lead. In three weeks, a lead plate one inch and a half square, lost 2·53 grains in weight, which is exactly the loss sustained in distilled water in the same time; and crystals of carbonate of lead were formed in profusion.

The water of Loch Lomond is a less familiar instance of the same kind.

Loch Lomond is twenty miles long, and at its southern or outlet end, rather more than four miles and a half wide. Its average elevation is only 22 feet above high-water mark. Eight miles north of its outlet it suddenly contracts at Ross Point to rather less than a mile across; and the northern division of twelve miles in length varies in breadth between a mile and only a fourth so much. The lower wide division of the loch, at a short distance from the shore, varies in depth on the whole from 8 to 12 fathoms; and these soundings continue till near Point Ross, where there is a rapid increase to 32 fathoms. This continues to be the average in the middle of the lake, till at the next contraction in its width, opposite Rowardennan Point, where it singularly shallows at once to 9, 8, and 7 fathoms. A mile further up, after another swell, it quickly deepens at a new contraction at Rhuda Mor (the Great Point) to 65 fathoms; and for five miles further north the soundings first steadily deepen by degrees to 105 fathoms, and then shelve to 80 opposite Inversnaid; above which point the lake becomes both much narrower and greatly less deep (Admiralty Map). My observations on its waters were made near Tarbet, which faces the middle of the very deep five-mile reach, where the soundings in mid-channel are never under 85, and at one place, opposite Culness farm-house, attain the extreme depth of 100 and

even 105 fathoms,—the width there being barely three-fourths of a mile:

The surface water over these great depths is of remarkable purity. Its saline matter is very scanty, and the colouring organic matter equally so. Still it has a faint yellowish colour. On September 21st, the second day after heavy rain, incessant for twelve hours, a white porcelain basin, 4 inches in diameter, disappeared in 18 feet of water; on 11th October, after many days of alternate rain and drought, in 15 feet; and on 18th November, after four days of dry weather, in 14 feet, but in feeble sunshine.* After long drought there is little doubt that the colour would be less, for it will be seen subsequently, that as the streams pour in fresh supplies of water, there is reason to suppose that these penetrate little before they run off, and consequently the coloured flood water from the streams will colour for some time the superficial waters of the lake.

On 18th November, the water taken from the surface of Loch

* This is a good method of ascertaining the relative colour of waters if it be employed with due precautions. The trial should be made in sunshine—when the sheet of water is quite calm—between 9 A.M. and 3 P.M., so that the sun's rays may not fall too obliquely on the water, and with the back to the sun, and, best of all, on the shady side of a boat. If all these conditions be reversed, vision will penetrate scarcely half so deep as when they are all observed. In my recent trials I have not found a white object visible at a greater depth than 21 feet, viz., on Loch Lomond on the 6th May. But, from observations made many years ago, I am satisfied that, after long dry weather, some river waters will allow such an object as a white porcelain basin to be seen at a much greater depth, with due attention to the conditions now mentioned. Having a recollection of seeing it stated long ago, that the water of the Lake of Geneva was so clear, that objects could be distinguished in it at a very great depth, I applied to Dr Coindet of Geneva for precise information, for which he referred me to Professor Forel of Lausanne. To Professor Forel's kindness I am indebted for the following interesting facts:—In the spring of 1869, using a white-painted sheet of iron, 15 inches by 12, he found that the utmost depth at which it could be seen was 13 metres, or 44 feet. The transparency is much affected by locality, and very much too by season. In winter and spring it is greatest, in summer and autumn least. In the Bay of Morges, objects may be seen distinctly at the bottom in winter at a depth from 13½ to 20 feet, while in summer they are barely visible through 7 feet. This difference is greatest near the shore, at the bottom of bays, and near villages or towns. It is least around promontories, far from land, and at a distance from human habitations. In autumn the change from obscurity to transparency usually takes place early in October, and is completed in three days; in summer, the reverse change takes place

Lomond over a depth of 102 fathoms, or 612 feet, presented in a 16-inch tube as exactly as possible the same degree of faint yellowish hue as the water of Loch Katrine. - Evaporated to dryness, it left a pale, greyish film, amounting to a 33,000th of the water. It had only 0.70 degrees of hardness by Clark's soap-test. Of the other liquid reagents, acetate of lead alone caused at once a slight haze; oxalate of ammonia and nitrate of silver had at first no effect, but in time caused an extremely faint haziness; nitrate of baryta, and ammoniacal phosphate of soda had no effect at all. When the water was much concentrated, however, sulphates, carbonates, and chlorides, as well as the bases, lime, soda, and magnesia, were clearly indicated by their ordinary tests, exactly as in the springs and streams of the adjacent country.

I examined also the water taken at the same place from the bottom at the depth of 102 fathoms. This differed in some respects from the surface water directly above it. It contained the same salts. But nitrate of silver indicated rather less chlorides; acetate of lead more carbonates; the soap-test denoted a trifling additional hardness, namely 0.74 degrees, and the total solids amounted to a 28,000th instead of a 33,000th. Farther, about the beginning of May, and is more gradual. By filtering a large quantity of turbid water, he found the obscuring cause to be a collection of amorphous dust, living and dead diatoms, vegetable debris, a few living infusoria and crustaceans, and debris of insect larvæ and microscopic crustacea. They naturally collect slowly in the summer; but the first cold of approaching winter sends them quickly down with the water as it cools.

In the case of Loch Lomond, these inquiries of Professor Forel would lead one to expect little influence from organic or inorganic dust in obscuring water where it is so deep as at the places chosen for my observations. Accordingly, the surface water was remarkably free from turbidity, or deposit on standing at rest. But the yellowish colour, faint though it be, constitutes a no less powerful obstruction to the penetration of light. The depth of colour, and consequently the transparency, vary at different periods, not so much with the seasons as with the times of floods. In advanced summer and in autumn, the floods increase the colour decidedly, and lessen for a time transparency. But my single observation on 6th May, when I found the transparency greatest of all a few days after heavy north-east rain, raises a question whether floods have the same effect in spring or the end of winter. A probable reason for the contrary may be, that the soluble matters of the peat-fields and stream-courses, developed by heat, growth, and atmospheric action in summer and autumn, are much exhausted by the frequent winter floods before the arrival of the floods of spring.

although the colour is the same at the bottom as at the surface, and very slight, it is distinctly deeper in shade when seen in a 16-inch tube; and the film left on evaporation, instead of being light grey, is of a rather deep yellowish-brown tint.

[*May 16th, 1872.*—As supplementary to these observations, I may here add the following, which I had an opportunity of making on the 10th of last month:—During the five winter months intermediate between my previous visit in November, the winter had been unusually open. Until the middle of March, indeed, there had been very little frost, and no severe cold. During the latter half of March frosty northerly winds prevailed, but without any very great fall of the thermometer. In the last days of March and first three days of April, snow fell frequently, covering the Highland mountains to their bases. Ben Lomond and the adjacent Arrochar mountains shared in the change. On 4th April the wind veered to west and south-west; bright sunshine and warmth soon dissolved most of the snow, and this weather continued, with scarcely any rain, till after my visit. The ground around Loch Lomond was consequently dry, the hill streams very low, and the streamlets dried up, or nearly so.

The surface water corresponded with these antecedent circumstances. Frequent winter floods had swept from the mountains most of the soluble matter from their beds; and for some days the streams, reduced to rills, would have little remaining to remove from their stony channels. Hence the surface water was of great purity. A white porcelain basin, two inches in diameter, was visible at the depth of 16 feet, although a light breeze rippled the surface. In a 16-inch tube the yellowish colour was extremely faint. The solid contents amounted to only a 32,000th of the water, and lost a fourth by incineration.* Nitrate of silver occasioned in the water only the faintest haze, and oxalate of ammonia did not visibly affect it. The soap-test indicated 0.49 of hardness, which is equivalent to a 145,000th of carbonate of lime. In accordance with its purity this water acted powerfully on lead. Action commenced at once, loose crystals of carbonate of lead were formed

* 26,250 grains left 0.83 at 300° F., and 0.62 after incineration.

in abundance, and in twenty-three days a plate an inch and a half square lost 1.11 grain in weight.

The bottom water, taken where the depth was 594 feet, differed materially in these characters. The cistern brought up some finely comminuted peat-like matter, in which the microscope detected a profusion of various diatoms, and two species of active microcosmic animals. The colour of the water was deeper than that of the surface, and became the same not till the addition of half its volume of colourless distilled water. Nitrate of silver produced an immediate scanty precipitate, oxalate of ammonia scarcely any effect. The soap-test indicated 1.015 of hardness, which is the equivalent of a 69,000th of carbonate of lime. The solids amounted to a 16,000th of the water, and lost a third by incineration.* When the water was evaporated to a tenth of its volume, nitrate of silver indicated chlorides in abundance, nitrate of baryta sulphates feebly, oxalate of ammonia lime sparingly, and phosphate of ammonia magnesia faintly. The original water had no action at all on lead. The lead plate became dull in a few hours, but no other change ensued which the eye could discover; and in twenty-three days the plate, which originally weighed 405.73 grains, weighed 405.74 grains.

These differences between the bottom and surface waters were so great, that it became desirable to repeat the examination, which I was able to do on the 6th of the present month. A good deal of easterly rain had fallen for some days until two days before this visit; but the hill streams had already become low. The waters were collected near the same place as before,—the bottom water from a depth of 94 fathoms, or 564 feet. The cistern brought up, as formerly, some peaty-like matter, which speedily subsided, and was promptly removed by decantation. Both specimens of water were very pure. But the bottom water was more affected than the surface water both by nitrate of silver and by oxalate of ammonia, and its colour was decidedly deeper, so that fully more than half its volume of colourless distilled water required to be added, to produce the feeble tint of the water from the surface.† The peaty matter

* 13,125 grains left 0.82 grains at 300, and 0.55 after incineration.

† The cistern which brought up the water was new, made of copper, and furnished, for valves, with spherical copper balls resting on hemispherical beds,

was found by microscopical examination to abound in diatoms and skeleton tissues of graminaceous and other vegetables. The bottom water contained a 25,000th of solids.

It has been proposed, in projects for introducing lake water into a town for domestic uses, to draw the water from a considerable depth, instead of from the surface, under the supposition that the deep water is the purest. The preceding observations show that this is a mistake, at least in the case of some lakes. On every occasion I have found the water of Loch Lomond somewhat more saline in its deepest parts than at the surface immediately above, and decidedly more coloured. The cause is easily understood, if the preceding chemical examination be taken in connection with the observations to be subsequently made on the temperature of Loch Lomond at various depths. For the results of both inquiries concur in indicating that, in the very deep parts, there is a vast body of still water which undergoes little, or, perhaps, no change or movement, and which, therefore, at the bottom, will become impregnated with whatever is soluble in the bed on which it rests.

Let me now change the scene to the hills and the waters of the Lowlands.

In the course of late notorious proceedings in this city for obtaining a more abundant water supply, it was stated by good chemical authorities that the water of St Mary's Loch in Selkirkshire, although of remarkable purity, does not exert upon metallic lead that eroding action which is a singular property of all pure waters previously subjected to trial. This statement was so opposed to the principles regulating the action of waters upon lead, as propounded by me so long ago as 1829, and also to the facts brought forward both then and in a paper read to this Society in 1842, that I resolved to investigate the question for myself.

This undertaking, in spite of my strong repugnance and steady refusal to be involved on either side of the Edinburgh water-controversy, led indirectly to my being compelled to concern myself with it as a parliamentary witness. But let it be clearly understood

and it was never used except for these experiments. The cistern was emptied at once into stoppered bottles on being drawn into the boat, and was carefully dried in a current of air with the valves open.

that my inquiries were undertaken quite irrespective of all controversial proceedings, parliamentary or otherwise, and for a purely scientific object—in which point of view alone I shall now proceed to state them. In the present place, I shall notice the lead question slightly, reserving that inquiry for another head of my observations. At present I have to say a few words of other matters which arose incidentally before me in the course of my inquiries.

St Mary's Loch is a lonely lake, retired among the hills of Selkirkshire, 37 miles south from Edinburgh. It is three miles long, and about half a mile in width at its broadest parts; but it may be said to be prolonged nearly another mile by the Loch of the Lowes above it, which is separated only by a space of 150 yards, through which the upper loch is joined to St Mary's Loch by a small stream. The lake in most parts shelves rapidly to a depth of 30 or 40 feet; in various parts it is said to deepen to 80, 100, and even 150 feet; and at a place pointed out to me as the deepest, I found 144 feet of water. It discharges itself in a goodly body of water, by a broad, shallow outlet to constitute the Yarrow Water. This joins the Ettrick a mile and a quarter above Selkirk; and the united waters, under the name of Ettrick, are poured, after a course of about four miles more, into the river Tweed. The Yarrow runs over 11 miles in a right line, but 14 miles by its windings, in a very stony channel, obviously of great width in floods.

The country of the Yarrow and St Mary's Loch is almost entirely pastoral, except where covered at the lower end of the stream by the beautiful woods of Bowhill, Philipshaugh, Hangingshaw, and other country seats. Around the lake itself the land may be described as consisting purely of pastoral hills, the attempts at arable culture being as yet very limited, and wood hitherto a scanty and stunted ornament. The level of the lake is almost exactly 800 feet above the sea. It is bordered everywhere, and abruptly, by hills rising from 750 to 1000 feet above it, showing long sky-lines, and steep slopes which present no rocks, no woods, nothing but smooth grass, unbroken save where scored by a few stream courses, mostly waterless in dry weather. But the Meggat Water is a considerable permanent stream, seven miles in direct length, which falls into St Mary's Loch about its middle line on the north; and the Little Yarrow, three miles in direct length, feeds the Loch of

the Lowes at its upper end. These streams, though short, are voluminous, because constantly supplied by numberless hill tributaries.

A traveller on the loch-side sees no peat anywhere. The district was therefore pronounced by recent one-eyed visitors to be free from peat. An inquisitive observer might have suspected the reverse from one of the highest surrounding hills being called Peat-Law; and on the high sky-line of another, a telescope would have betrayed to him a very suspicious circumstance in a crowd of little peat-stacks. Any one, not content with creeping along the bottom of valleys, but familiar with the summits of the mountains of the Scottish Lowlands, would then have known that the sky-line seen from the loch-side is not,—as it very often is in the primitive mountains of the Highlands,—a mere ridge, but forms the edge of a great table-top, which, in most cases, is chiefly composed of peat. In point of fact Professor Geikie has shown last summer, from the Government Geological Survey, that a vast proportion of the hill-tops in the St Mary's district consists of peat table-lands.

The consequences which flow from this structure of the country are peculiar. In dry weather the high peaty summits of the hills will cease to supply moisture enough to drain into the streamlets which score their sides. These will then convey to the lake chiefly the drainage of the grassy slopes, and the produce of the scanty springs in the lower regions. But when a rain-flood sets in, the peat, whether previously dry or moist, will send down a profusion of peaty water. Had the Yarrow flowed as a river through the vale at St Mary's, the peaty flood would have been swept quickly down towards the sea; and in two or three days the waters would have recovered from their peaty impregnation. But the two lochs, with a superficial area of two square miles, store up the peaty water, and dole it out, like a compensation pond, for many days, until the arrival of a fresh flood to renew it. An embankment at the outlet, to increase the storage, would protract the outflow, and postpone still further the recovery of the water from impurity.

These facts and views could only occur to one familiar with the district, or going thither to study it for a practical object. When I first went to St Mary's Loch on the 12th and 13th June last, I

had no further acquaintance with the hill structure around, than that of an angler thirty years ago, when I probably looked more at what came out of the loch than at anything else concerning it. I consequently went prepossessed in its favour by the glowing account given of its extreme purity by its admirers. My surprise, therefore, was not small when my very first observation showed that its water was yellow. My visit was made in circumstances highly favourable to its condition, in splendid sunshine, being the last two days of six weeks of extraordinarily dry weather, broken only by a few light showers, sufficient to freshen the grass, and little more. But I found that my white porcelain basin became at once yellowish when dropped into the lake, acquired a lively amber hue at the depth of 3 feet, and disappeared entirely at 12 feet, while the sun shone brightly on the spot. I remembered well, however, having once distinguished small pebbles in the Dumfriesshire Esk through 16 feet of water, when spearing salmon in a still pool, and on another occasion through 21 feet in a pool below the Bracklinn Falls, near Callander. I afterwards tested the colour of the loch water on a small scale, and showed it satisfactorily to many, by comparing it with the water of Edinburgh of the same date in two narrow glass jars, 20 inches in height, with a circular disc of white porcelain at the bottom. The porcelain was of unstained whiteness as seen through the Edinburgh water, but of a lively amber tint when looked at through the water of St Mary's Loch. The difference was not less marked in the narrow 16-inch tubes. Even in dining-table water-bottles, placed on a white tablecloth, the colour of the loch water was such as to make it evident, that certainly nobody would drink it who could get the other. I may add that, when I revisited the loch on 8th September, also in bright sunshine, I found that my porcelain basin disappeared entirely in eight feet of water; and, nevertheless, there had been previously ten continuous days of absolutely dry weather.

On the 12th and 13th June, I saw in the water no want of the water-fleas, which excited so much interest and heat in the late controversy. It may create additional interest with some to be told that three months later they were decidedly bigger, busier, and altogether more deserving of their vernacular name.

Before speaking of the chemical composition of the water, let

me finish what may be said of the physical characters of the loch, by noticing one not yet adverted to. Visitors in the dry season, when the waters of the lake are somewhat shrunk, have been much struck with the beauty of its border,—its “silver strand.” This is owing to a uniform beach of crowded, chiefly angular, or partially rounded, light-grey coloured stones. The colour, however, is not their own, but belongs to a generally dense covering of a dried-up matter, composed of a multitude of various diatoms entangled in the delicate lines of a finely fibrous conferva. In the fresh state this investing matter is dark greenish-brown, close, and slimy. The stones, therefore, give the loch, even in its shallows, a disagreeable, dark, deep appearance, abruptly defined by the water’s edge. But all of them out of water acquire, in drying, a light grey or greyish-white hue. Every scientific visitor has observed, and some have carefully examined, these stones and their covering. But, so far as I am aware, no one has noted their full significance; of which more presently, when I come to speak of the Yarrow.

The water of the loch, though it is coloured, is a pure water,—in the sense that it contains very little solid matter in solution. It has been repeatedly analysed, and found to contain rather less than a 20,000th part of total solids. Mr Dewar, the latest analyst, I believe, found a 22,440th,—of which the inorganic salts constituted two-thirds [a 37,000th], and the organic matter one-third [a 55,500th]. The chief inorganic salts are the same as in the mica-slate streams and lochs of the Highlands, and much in the same proportion to one another. The hardness of the water was found by Mr Dewar to be 1·30 degrees by the soap-test, or nearly twice that of Loch Lomond surface water. Other chemists have found more solids, some less. My own results, with water collected on 13th June, show more saline, and rather less organic, matter; which is no more than might have been anticipated from the long antecedent very dry weather. I found the solid contents dried at about 300° F. to be a 15,000th of the water; one-fourth of this was destroyed by slow incineration at a low red heat; and the hardness was 2·0 degrees of Clark’s soap-test scale,—which is about the fourth part of that of the present Edinburgh water supply. Water collected three months later, on 8th September, after ten days of complete drought, which, after a few days of showery weather,

followed the very heavy floods of 24th August, contained more colouring matter, exhibited less action with the ordinary liquid tests for the inorganic salts, and had a hardness of 1·4 degree only. I have no doubt that this water corresponded in all respects very closely with the specimen examined by Mr Dewar.

Thus, it appears, that the waters of St Mary's Loch—which, with the exception perhaps of those in the primitive districts of Kirkcudbrightshire and Wigtownshire, may be taken as a type of the lowland lochs at large—differ from the waters of the Highland lakes in containing more solid matter, a little more saline matter, and decidedly more colouring organic matter, and in being considerably harder, though really belonging to the "soft" waters too. Another difference is that they vary more with the season, the salts becoming rather more abundant in long dry weather, and the colouring matter clearly abounding more during and after floods. Finally, a remarkable difference in property, to be discussed by-and-by, is, that unlike the waters of the Highland lochs, that of St Mary's Loch does not erode lead. But first let me say a word or two about the Yarrow Water, by which this lake discharges itself.

The Yarrow, before uniting with the Ettrick, winds for 14 miles through a narrow, bare, chiefly pastoral vale, bounded by gently sloping hills. It is joined in this course by twenty-two tributaries, of which only three or four are considerable streamlets, the others being mostly rills, apt to be dried up, or nearly so, in dry weather. The waters of the chief tributaries contain in the dry season more salts than the main stream itself, but very much less colouring matter, two of them, indeed, none at all appreciable even in a 16-inch tube. The channel of the Yarrow is wide and stony, and the stream shallow, and for the most part turbulent. In the 14 miles it falls 220 feet. Its banks present very few human habitations.

These circumstances are favourable to the gradual diminution of organic impregnations, partly through the decomposing influence of fresh earthy salts added here and there by little tributaries, partly by the slow oxidation, to which Liebig gave the name of "Eremacausis,"—"quiet" or "slow burning." My attention was turned very long ago, before the publication of Liebig's views on this subject, to the rapidity with which, by natural processes,

streams rid themselves of the unnatural impurities introduced into them by sewage, and by some of the manufactures. But I am not aware that the process of clearing has been watched with care in circumstances altogether natural. It occurred to me, at anyrate, that we have in the Yarrow a most favourable opportunity for tracing this process in the case of a natural water of a remarkable kind, under the operation of natural causes alone. On the 8th of September, therefore, I examined the course of the Yarrow with some attention.

In its descent from St Mary's Loch, it is first joined by two unimportant rills, at that time nearly dried up by ten days of previous drought. A mile and a half below its outlet, it receives from the north its largest tributary, the Douglas Burn, which drains a very hilly country about five miles and a half long and four miles wide. This stream, indeed, was at the time a small rill, compared with the strong body of water in the Yarrow. But it was interesting in this respect, that its water, containing more saline matter than the main stream, and possessing the hardness of 4·90 degrees, presented no colour at all, even when examined in a 16-inch tube. This last fact is remarkable, because the Douglas Burn comes very much from peat-topped hills, so that either the peaty water of floods soon runs out in dry weather, and spring-water is alone left, or the water clears itself by *eremacausis*, or in its upper course in the way in which purification seems to be brought about in the Yarrow.

For, when I came to examine the Yarrow immediately above the junction of the Douglas Burn, I found to my surprise that the colour, which at the outlet was such as to render a porcelain basin invisible when sunk 8 feet only, was already so much reduced, in the course of a mile and a half, as to approach the faint hue of the waters of Loch Katrine and Loch Lomond. There was also a slight increase of salts, as shown by the ordinary liquid tests, and also by the hardness of the water having increased from 1·4 to 2·40 degrees.

A mile lower down another principal tributary, but inferior to the Douglas Burn, falls into the Yarrow on the right, the Altrieve Burn, which, however, I had not time enough to examine. Two miles further on a similar streamlet joins from the right, the

Sundhope, which, too, I could not examine. Other trifling rills, almost dried up, join between the Douglas Burn and Yarrow kirk, seven miles from the outlet of the lake. This point was a good one for studying the joint effect of atmospheric exposure through constant agitation, and of the influx of several brooks, all probably containing more salts than the main stream itself. Here I found that the soap-test indicated a further increase of hardness to 3·0 degrees, and that the yellow colour in a 16-inch tube was still further reduced, but not much.

In the next three miles and a half there are six little tributaries, all at the time of my visit insignificant, and some quite dried up, till we arrive at the Lewenshope Burn, which drains from the north a considerable stretch of the Minchmoor range, described to me as generally stony hills, without much peat. This water possessed 6·5 degrees of hardness, and so little colour that it was barely appreciable in a 16-inch tube. In the remainder of its course the Yarrow is joined by five more rills, either almost dried up when I was there, or appropriated in a great measure for the supply of mansions. Four hundred yards above its junction with the Ettrick, I found its water to possess, as at Yarrow kirk, seven miles higher up, 3·0 degrees of hardness, so that the comparatively saline water of the Lewenshope had not materially increased the salts of the Yarrow. But the colour was still more reduced, so as to be very faint indeed, equally so with the colour of the water of Loch Lomond.

Thus the principal loss of colour takes place in the first mile and a half of the river's course; but there was also a very appreciable additional improvement in the longer course below, and the final result was a nearly total removal of colour.

To what is this change owing? Does it depend entirely on the intermixture of earthy salts from the tributaries, and on eremacausis? I apprehend that these causes will scarcely account for the great change effected in the first mile and a half. There may even be a doubt whether peat-extract is particularly subject to the process of eremacausis. It is well known to be a preservative of organic matters, which it could scarcely be were it very subject to decay itself; and I find that a solution of it without any saline matter, has undergone no change in a warm room, in a half-filled

bottle, during six months. But there is a more potent agent at work in the Yarrow. The dark, green-coated stones of the loch, with all their characters unreduced, pave the entire channel of the stream as low at least as the confluence of the Douglas Burn, and, with a less abundant covering, so low at least as Yarrow kirk, seven miles from the outlet of the lake. But there is nothing of the kind in the chief tributaries. At the junction, for example, of the Douglas Burn, there is an abrupt line of demarcation between the dark green, slippery stones of the Yarrow, and the stones of the tributary, which are as naked as if they had been scrubbed clean with a brush. I do not well see how to escape the conclusion, that the confervæ and diatoms of the stones live at the cost of the peaty matter from the loch,—that peat-extract is their food and is consumed by them. This is a ready explanation of their excessive growth on the stones of the loch. The want of such food equally explains the comparative absence of them from the stony banks of Loch Lomond, and the stony channels of all the streams of the adjacent mica-slate district.* Indeed, in the opposite circumstance—in some mountain tarns of the district, resting, as they may, on peat, and surrounded by it—the slippery, dark green, stony bottom is no uncommon occurrence.

If these views be correct, it is easy to appreciate both the unfavourable significance in a lake of a dark-green bottom of stones, densely covered with confervæ and diatoms, and likewise their value in a running stream; and it may be well also not to let the imagination run away luxuriating in every “silver strand” that meets the eye.

The Temperature of the Deep Fresh-water Lakes of this country has no connection with the preceding inquiries, further than that my observations on the subject arose incidentally while I was carrying on the inquiries in question. The results I have obtained may interest the cultivator of physical geography, if I am right

* It has been said that stones covered with green confervæ and other diatoms do occur in Loch-Lomond. They do in bays and other shallows; but the covering is very thin; and the line of such stones is narrow. Where deep water is near there are none at the edge, and where they do occur the dry stones close to the edge appear quite clean.

in supposing that no prior observations of the kind have been made on our deep fresh waters. [See, however, p. 574.]

In the course of the discussion of the St Mary's Loch water-supply scheme, opposite opinions were expressed as to the relative advantage of drawing the water from the surface of the lake, or from a considerable depth; and weighty arguments, of a speculative nature, were advanced on both sides of the question. It occurred to me, therefore, to consider what becomes of the deep water. Does it escape as that of the surface must do? And if so, How? It appeared to me that during a winter of such protracted cold as that of 1870-71, the water at the bottom would probably acquire so low a temperature, that it must long remain there. For it can only rise again, either by its temperature falling below $39^{\circ}\cdot5$, when its density decreases instead of continuing to increase, or by being heated by the heat of the earth beneath; and it is unlikely that the temperature of the entire water of a deep lake will fall lower than $39^{\circ}\cdot5$, or indeed so low, in this latitude, and the heat derived from the earth, in our latitude at the elevation of 800 feet above the sea, must be inconsiderable. It is well known that the bottom cannot be heated by conduction from the summer heat of the atmosphere above, as in the case of a solid substance; and the effect of the penetration of the sun's rays, by which the water is heated to a certain depth, cannot descend very low in a lake, the water of which is, like that of St Mary's Loch, so coloured as to render a very white object invisible at the depth of 8 or 12 feet. The conclusion would be that the water at the bottom of the deep parts of the lake, in the absence of strong springs—of the existence of which there is neither proof nor probability—will remain at the bottom for want of a current during the whole warm season, and perhaps longer.

When I was first at St Mary's Loch on 12th and 13th June, I had no suitable thermometer for taking observation of deep temperatures. But Mr Dewar kindly undertook to make the necessary trial a few days later in the same month. With a Six's thermometer, whose graduation was subsequently tested and found correct, he ascertained that in 150 feet soundings, the temperature, being 56 at the surface, was 46° at the bottom. When I revisited St Mary's Loch on 8th September, nearly three months afterwards, the inter-

mediate weather having been generally fine, I found, with the same thermometer, in 96 feet of water, near the head of the lake, 56° at the surface and 54° at the bottom; and in 144 feet of water, in the middle of the loch, exactly opposite the 17th milestone from Selkirk, I obtained 55° at the surface and 47° at the bottom. During three of the warmest months of last warm season, the heat of the earth, or the sun's rays, had heated the water at the bottom by one degree of Fahrenheit only. I do not well see how that water can ever rise from such a depth, unless its temperature during the winter should fall below $39^{\circ}5$, which is not probable.

I regret I did not take successive observations at several depths in order to fix the upper limit of the cold substratum of water. My time was short, for my main object on that occasion was the changes undergone by the river Yarrow, and I contemplated a chain of observations in more favourable circumstances at Loch Lomond. I went to Loch Lomond on four occasions for the purpose, viz., on September 14th, September 21st, October 11th and 12th, and November 18th. As accurate observations were made only on the two last occasions, I shall refer to the others only incidentally.

On 11th October, at 3 p.m., the atmospheric temperature on land being 48° , and that of the surface water everywhere over deep soundings 52° , I found in 103 fathoms of water opposite Culness, with a Six's thermometer by Casella, which, though not specially protected against high pressure, was believed to be proof against such pressures as it was to be subjected to, that a temperature of 43° was indicated at 200 feet, and $41^{\circ}8$ steadily at 400, 500, and 618 feet. Next forenoon at 11, I repeated my observations about a mile lower down opposite Tarbet in 87 fathoms. The air was singularly still, the atmospheric temperature on land 44° , and that of the loch on the surface 52° , exactly as on the previous day. The following successive temperatures were obtained at various depths:—

Surface,	$52^{\circ}0$	150 feet,	$44^{\circ}5$
25 feet,	$51^{\circ}5$	200 „	$43^{\circ}0$
50 „	$50^{\circ}2$	300 „	$42^{\circ}0$
75 „	$50^{\circ}0$	400 „	$42^{\circ}0$
100 „	$49^{\circ}5$	518 „ bottom, .	$42^{\circ}0$

It will be observed that these temperatures correspond almost exactly with such observations of the previous day as were made a mile and a half further north at the same depths, where the soundings were 618 fathoms. The bottom temperatures also corresponded with what I had observed with a different thermometer on September 21st, three weeks earlier. Using a cistern with proper valves, constructed by Mr Adie, for bringing up 96 ounces of water from the bottom, with a simple thermometer in it, I found that on September 21st, when the surface temperature was 54° , and also on October 11th, when it was 52° , the thermometer, on the instrument arriving at the surface, indicated 44° in the water brought up from the bottom, both in 87 and 103 fathoms of water. As the heating of the cistern in ascending must have been very nearly or altogether the same on both occasions, it follows that the corrected temperature at the bottom, as on 11th October, was 42° on 21st September.

On 18th November I found it to be also the same. Cold weather had set in for a week before. The air was frosty, the ground dry and hard, the atmosphere very clear and perfectly still. Near the lower end of the loch, where the highway first touches it, the air temperature was 33° at half-past eleven. At Tarbet at one P.M., it was on land, but at the water's edge, 37° ; in the boat, in the middle of the loch, two feet above its surface, 42° ; and in surface water, over 610 feet soundings, 46° . At the bottom, by a Casella's thermometer, protected against pressure, and corresponding exactly in its graduation with the unprotected one previously used, the bottom temperature was again 42° . My design to make at the same time another complete series of observations, was prevented by unexpected delays shortening my time very much, so that I had to confine myself to a single additional observation, for determining more nearly the upper limit of the cold substratum of water. At 250 feet I obtained a temperature of $42^{\circ}25$, and consequently the upper limit of the water at 42° must have been as nearly as possible at 270 feet in 610 feet soundings.

Before drawing confident deductions from these observations, they require to be repeated at other seasons. But in the meanwhile it may be well to see what are likely to be the results.

It is plain, in the first place, that in a deep lake in this latitude, there is a very gradual and slight increase of cold in the warm season for the first hundred feet, viz., by $2^{\circ}5$ only, then a sudden descent by $5^{\circ}0$ in the next 50 feet only; next another slow descent by $2^{\circ}5$ in 150 feet; and finally, below that a great substratum of 250 feet of water, and at a deeper spot of no less than 350 feet, at the uniform temperature of 42° , or a little less. Next, at Loch Lomond no change took place in the temperature of the bottom water during two months of unusual warmth for the months of September and October, and no change at 300 feet from the surface during five weeks prior to the middle of November.

It seems certain that the temperature of the great substratum of cold water cannot be raised after the middle of November, when the cold season has fairly set in. Whether it is to be lowered during winter, or whether the substratum, without becoming colder, will merely have its upper level raised, is a question to be settled by observation at an early period of next spring.

In the meanwhile, abstracting the highly improbable existence of strong springs at the great depths I have mentioned, it does not appear how this vast cold substratum could have been moved during last summer and autumn. Neither does it appear how it can be moved during the winter, unless the equally great stratum above it acquire a lower temperature than 42° , and so take its place; for the uniformity of the bottom temperature between 21st September and 18th November, when no additional cold could descend through the warmer stratum above, is sufficient proof that the influence of the heat of the earth beneath is too feeble in this latitude to make itself sensibly felt by motion of the water.

Thus there is a probability, that when water once descends to so great a depth as the bottom of our deep lakes, it cannot ascend again except under rare and extraordinary circumstances. If this view be correct, the movement of the waters of a deep lake towards its outlet for escape, must be confined very much to the warm water at its surface, or to no great depth, and, therefore, mainly to the waters which are constantly supplied on all sides by its feeding streams. This must be the case in summer and in autumn; it may be the case in winter also

[May 18, 1872.—Circumstances having delayed the publication of the Society’s Proceedings, I take this opportunity of adding the result of recent and conclusive observations. These were made on 10th April and 6th May, as near as I could to the place of the observations described above.

April 10.—The weather on this occasion was very fine and favourable for my purpose. During the whole winter period after November 18th, the date of the last observations, the weather had been remarkably open. The mean temperature of the atmosphere for the five intervening months, as kindly calculated for me by Mr Buchan, Secretary of the Meteorological Society, from observations at Balloch Castle, at the southern end of the loch, was 1°·4 higher than the average for the same months for thirteen previous years.* Consequently, the same influence of the winter season on the temperature of deep waters cannot be expected as in ordinary winters, or in a hard winter, such as the preceding one of 1870–71.

When I made my observations, about 3 P.M. on 10th April, the temperature of the air on land was 55°; and on the water, one mile from the shore whence the wind blew, it was 53° in the boat, scarcely 2 feet above the surface of the lake. The following temperatures were obtained, at various depths in the same place:—

Surface, . . .	43°·0	150 feet, . . .	42°·1
50 feet, . . .	42°·6	200 „ . . .	42°·0
75 „ . . .	42°·2	594 „ bottom,	42°·0
100 „ . . .	42°·2		

These observations were made with Casella’s protected thermometer. The thermometer in Adie’s cistern, for bringing up water from the bottom, also stood at 42° when brought up to the surface, the temperature of the upper warmer stratum being much too low to affect the cistern in its passage.

May 6.—Between 10th April and this date the weather varied

* In the course of his calculations Mr Buchan arrived at the interesting fact that the average mean temperature of the air during the six cold months of these years, at the level of the lake’s surface, was 41°·7 from November 18 to April 10, or very nearly that of the deep substratum.—See subsequently, for his observations, the later *Proceedings of the Society*.

as to warmth; but there was a large proportion of sunshine, and little rain, till three days before, when there was a heavy fall with an easterly wind. The temperature on land, within fifty yards of the water, was 55° . The following observations were made at 2 P.M.:—

Surface, . . .	$44^{\circ}\cdot5$	150 feet, . . .	$42^{\circ}\cdot7$
25 feet, . . .	$43^{\circ}\cdot7$	175 „ . . .	$42^{\circ}\cdot6$
50 „ . . .	$43^{\circ}\cdot5$	200 „ . . .	$42^{\circ}\cdot5$
75 „ . . .	$43^{\circ}\cdot2$	250 „ . . .	$42^{\circ}\cdot4$
100 „ . . .	$43^{\circ}\cdot1$	300 „ . . .	$42^{\circ}\cdot1$
125 „ . . .	$42^{\circ}\cdot8$	574 „ . . .	$42^{\circ}\cdot1$

The thermometer in Adie's cistern, when brought up full of water from the bottom, but raised rather deliberately, stood at $42^{\circ}\cdot5$.

It appears, from these and the preceding observations, that in the deep parts of Loch Lomond there is a substratum of water of several hundred feet, which, between the end of September last and 10th April, has been steadily of the temperature of 42° ; and that during last winter no other change has taken place, in relation to temperature in or near it, than that the level of the cold substratum rose in the interval between 70 and 100 feet. A winter, materially colder than the last unusually mild one, would at least raise that level still nearer the surface. Whether it may reduce the temperature still lower than 42° , is a question which remains to be decided by future observation. It is still also a matter for observation, whether the temperature of the substratum may not rise a little during summer. For it may be reasonably said, that the unusually hard winter of 1870–71 might have lowered the temperature of the substratum in April of last year below that observed in April of this year after a very open winter, and, consequently, under 42° , which was the temperature observed in October. But the difference, if any, cannot be considerable; for it can only arise from the heating power of the earth on which the water rests.

The water of a lake is heated in summer and autumn in three ways—the heat of the atmosphere, that of the sun's rays, and that of the earth. The atmosphere will communicate its heat to so much of the superstratum only as is disturbed, more or less, by the wind; and, therefore, cannot penetrate many feet. The tempera-

ture of the earth at the bottom, from 500 to 600 feet under the sea-level, should be by theory about 60° in the deepest parts; but, considering the very low conducting power of the rocky structure of the earth, its heating power over so vast a bed of cold water must be very feeble. The sun's rays are at once the most energetic heating power, that which penetrates deepest, and that which alone can sensibly heat any part of the superstratum of water underneath the thin bed near the surface, where it is aided by the warmth of the atmosphere, and the stirring of the water by the wind. But there is a limit to the sun's penetration in such depths, when the water, as in the case of Loch Lomond, is coloured, however slightly. It has been imagined that the presence of springs at the bottom may be a fourth source of influence over the temperature. If there be any springs there, the effect must be to heat the water. But, as there are no springs in Scotland which rise above the surface, or present other proofs of owing their place to unusual sources of pressure, it seems most improbable that any are so constituted as to overcome the pressure which exists at the bottom of a very deep lake.

Every known consideration,—the great thickness of the cold substratum, its steady low temperature, and its greater colour than at the surface—contributes proof that this substratum can undergo little or no movement, unless an unusually hard winter should displace it by colder water from above.*]

The previous observations have extended to so great a length that I must postpone till another opportunity the remarks which I have prepared on the third of my promised topics—the Action of Water on Lead.

The following Gentlemen were elected Fellows of the Society:—

ALEXANDER H. LEE, Esq., C.E.

ROBERT LEE, Esq., Advocate.

JOHN ANDERSON, LL.D.

* While the preceding statements were passing through the press, my attention was called to similar observations in Sir John Leslie's article on Climate in the "Encyclopædia Britannica," by Saussure on the Lakes of Geneva, Thun, and Lucerne, and by the late eminent engineer, Mr James Jardine, on Loch Lomond and Loch Katrine in 1814. Their observations are not entirely concordant with those given above. I contemplate further observations which may reconcile them.