PROCEEDINGS

OF THE

MANCHESTER

LITERARY AND PHILOSOPHICAL SOCIETY.

VOL. XX.

SESSION 1880–81.

MANCHESTER:

PRINTED BY THOS. SOWLER AND CO., 24, CANNON STREET.

LONDON: BALLIÈRE, 219, REGENT STREET.

1881.

NOTE.

The object which the Society have in view in publishing their Proceedings is to give an immediate and succinct account of the scientific and other business transacted at their meetings to the members and the general public. The various communications are supplied by the authors themselves, who are alone responsible for the facts and reasonings contained therein.

INDEX.

ERRATA.

Page 101, line 7 from bottom, and page 102, line 7 from top, for "bent" read "beat."

Page 104, line 1, for "Chayne" read "Cheyne."

PROCEEDINGS

OF THE

LITERARY AND PHILOSOPHICAL SOCIETY.

Ordinary Meeting, October 5th, 1880.

R. ANGUS SMITH, Ph.D., F.R.S., &c., V.P., in the Chair.

"Colorimetry, Part VI. On a Theory of Mixed Colours," by JAMES BOTTOMLEY, B.A., D.Sc.

In some experiments which I was making on the absorption of light, I needed surfaces of different degrees of whiteness. To obtain such surfaces I mixed black and white powders in various proportions. They were blended by shaking in a bottle and grinding in a mortar. In some cases the mixture was reduced to a flat surface by pressure, in other cases, a little water was added so as to form a paint, and with this pieces of cardboard were covered and dried. Although it was not necessary for my purpose that I should quantitatively assign the degrees of whiteness in each case, yet such a question occurred to me in the preparation of these powders. In this matter little has, I think, been done. Newton, in his Optics, informs us that he mixed powders of different colours in such proportions as to form a grey, and in later times it has been proposed to estimate the degree of blackness of different bodies by finding the quantity of some white powder, which, on admixture, will yield some standard tint. But no one has I think ever considered the law of intensity of colour when we mix a colour with white or black. Such a question is interesting to the artist, to the colour mixer, and to the chemist. The artist in water-colour, if he wishes to reduce the strength of any pigment, can do so by additional water, but the painter in oil or distemper, if he wishes to accomplish a similar object, has to mix with some opaque white. This, then, is the matter which I first propose to consider. A coloured powder and a white powder are intimately blended; what is the law of the intensity of colour? As a typical case, I take the mixture of black and white, because it was such a mixture that suggested this enquiry. In what follows I suppose the powders to consist of indefinitely small particles, which do not exert any chemical action on each other. Suppose that we take a mass of some white substance, and add to it a small quantity of some black substance; then we shall take away some portion of its whiteness—if w denote the whiteness lost, and W the initial whiteness—then the remaining whiteness would be W—w. If now we add another unit of the black, it might at first sight appear that the remaining whiteness would be W—$2w$, and after the addition of n units, that the remaining whiteness would be W—nw. For some experiments which I was making, I had prepared eight grey tints by mixing $BaSO_4$ with carbon; the quantity of $BaSO_4$ being 10 grms. in each case, and the carbon increasing from 0·006 grms. to 0·048 grms. The difference in tint between the successive mixtures seemed to diminish more rapidly than seemed consistent with such a law of diminution of whiteness. The difference between the seventh and eighth mixture was almost inappreciable, but according to the foregoing supposition, the difference between successive pairs should be the same.

On considering the matter further, I was led to the following train of reasoning. If we take equal masses of white of different intensities and to each add the same bulk of black, then in each case the whiteness lost will be a constant fraction of the initial whiteness. Suppose M to be the mass of the white, and W_0 its initial whiteness, let m be the mass of the black. After mixing with the white it will destroy some fraction of its whiteness; let this fraction be n. Then the remaining whiteness will be $W_0 - W_0 n$, this we may denote by W_1, and the mass will be $M + m$.

Suppose we repeat the addition of the black, the proportion being as before $M:m$. If x denote the black to be added, we shall have the proportion

$$M + m : M :: x : m$$

Whence $$x = \frac{(M + m)m}{M}$$

After this second mixture the whiteness will be $W_1 - W_1 n$; this we may denote by W_2; it may also be written $W_0(1 - n)^2$ by substitution for W_1, or still more briefly $W_0 R^2$ when $R = (1 - n)$.

Let the operation be repeated a third time, the proportion of the white mass to the black being still $M:m$. After the second mixture the mass became $\frac{(M + m)^2}{M}$. So if x denote the quantity of black to be added we shall have

$$\frac{(M + m)^2}{M} : M :: x : m.$$

Whence $$x = m + \frac{2m^2}{M} + \frac{m^3}{M^2}$$

The mass will now become $\frac{(M + m)^3}{M^2}$

If W_3 denote the whiteness we shall have

$$W_3 = W_2 - W_2 n = W_0 R^2 (1 - n) = W_0 R^3$$

If we continue the operation n times, then from the above law, if Wn denote the remaining whiteness we shall have $Wn = W_0 R^n$.

Also the mass will be $\frac{(M + m)^n}{M^{n-1}}$

I also used an independent method of reasoning. Suppose we have a white area A, then the quantity of white light given off in any direction, say normal, to the surface will be proportional to A; so that if W_0 denote the white light we may write $W_0 = \mu A$. Suppose now a great number of black points to fall on this surface, being equally distributed. Then the surface will appear to the eye of a grey tint, but grey and white are quantities of the same kind and are therefore comparable. What we call grey being a white of diminished intensity. Suppose a to be the area occupied by the black points. Then A—a will be the uncovered white area, and the quantity of white light given off by this will be $\mu(A-a)$; moreover this quantity of white light will appear uniformly diffused over the surface. If we denote it by W_1 we shall then have

$W_1 = \mu(A-a) = \mu A(1-\frac{a}{A}) = W_0 R$ when R is written for $1-\frac{a}{A}$.

Now suppose a second series of black points to fall on the surface. It might at first sight appear that the remaining white area would be A—$2a$; but on consideration this did not seem necessarily the case, for manifestly it supposes that the particles distribute themselves with some bias; that is, they prefer to fall upon a white surface; but suppose that they have no such bias, and that they will as readily fall upon a black as upon a white surface. Now the surface on which they fall is grey or a mixture of black and white. So we have this question in the distribution of the second black area (consisting of innumerable detached points), how much falls on the black surface and how much on the unoccupied white area? Let p be the portion that falls on the black surface and q the portion that falls on the white, now what will be the ratio of p to q? If we suppose the second series of black points to be fairly distributed, the portion which falls on the black surface will be to the portion which falls on the white as the areas of those surfaces, so that

$$\frac{p}{q} = \frac{a}{A-a} \quad \text{..................(1)}$$

$$\text{also } p+q=a, \quad \text{..................(2)}$$

and the remaining white area will be $A-a-q$. From (1) and

(2) we have $\frac{qa}{A-a}=a-q$, whence $q=\frac{a(A-a)}{A}$, and for the remaining white area we have the expression

$$A-a-\frac{a(A-a)}{A}=A\left(1-\frac{a}{A}\right)^2=AR^2$$

and the quantity of white light given off will be μAR^2; also this quantity of light will appear equally distributed over the whole surface; hence, if W_2 denote this white light we may write $W_2=\mu AR^2=W_0R^2$.

If we allow a third series of black points to fall upon the surface, and to be equally distributed, the remaining white ones will be AR^3, and if W_3 denote the quantity of white light

$$W_3=W_0R^3$$

If we suppose the operation to be repeated n times. The expression for the remaining white light will be W_0R^n. Hence the ratio of the initial to the final whiteness would be

$$\frac{1}{R^n}$$

Both trains of reasoning concur in giving a similar expression for the intensity of the whiteness. In some papers which I have contributed to this Society I have pointed out that the law expressing the intensity of transmitted light when we dissolve Q units of colouring matter in a transparent medium, is of the form $\Sigma a\kappa^Q$. Hence we have this curious result: when the intensity of an opaque white is diminished by mixture with an opaque black, the mathematical expression for the intensity of the whiteness is of the same form as if we had dissolved the black in a transparent medium and surveyed a white area through it. In the foregoing reasoning I have supposed the particles, after admixture, to distribute themselves without bias. It becomes a question of much interest, when we mix particles of heterogeneous matter is this always the case? Under some circumstances they may be brought within the sphere of molecular attractions, and these may have some influence in the distribution; in other words, it is possible to conceive that the particles will distribute themselves with some bias. Here again it seems to me that so far from such speculations on the intensity of colour of mixtures being fruitless, they may even extend the application of colorimetry; for while experimental agreement with the theory would strengthen the theory, even negation would have its value, and an investigation into the departures from the law might lead to interesting results, and give some insight into the operation of those molecular forces which separately elude observation, but whose joint effect must necessarily have some influence in determining the intensity of colour.

Some of the above reasoning applies to the case of turbid liquids, and I was led to the conclusion that a carbon diffusion would behave with regard to the extinction of light in the same manner that it would do if the carbon were actually in solution. The only difference in the reasoning is, that the different series of carbon points, instead of falling on one section, are distributed through a series of circular sections of the containing cylinder, these sections being parallel to the external white surface. As I have shown in another paper, the results of the experiments agree very well with the theory. So far I have considered the intensity of the residual whiteness when we mix black with white. The same course of reasoning might be applied to determine the residual colour when we mix black with any colour. Suppose, for instance, we take a mass M of yellow and let the initial yellow be Yo. Then, if we mix with it a mass m of black, we shall remove some fraction of the yellow; let this be denoted by nYo, so that the residual yellow is $Yo(1-n)$, or YoR. After n repetitions according to the proportions laid down in the case of black and white, the intensity of the residual yellow will be YoR^n.

Another problem is the mixture of white with some opaque colour, red for instance. Suppose we start with a white area A, then the quantity of white light given off normally may be denoted by μA. Suppose now a great number of red points to fall upon this surface and to be equally diffused, so that the eye does not perceive detached red and white points, but a surface uniformly tinted of a light red colour. Let a be the area occupied by the red points; then the quantity of red light we may denote by $\mu_1 a$, and the uncovered white area will be $A-a$, and the quantity of white light given off will be $\mu(A-a)$. Suppose now a second series of red points to fall upon the surface, and that they distribute themselves without bias, and also that there is no chemical action. Then the uncovered white area will be $\frac{(A-a)^2}{A}$ and the red area will be $A-\frac{(A-a)^2}{A}$ Hence after the second operation the light given off will consist of white light $\frac{\mu(A-a)^2}{A}$ and of red light $\mu_1\left\{A-\frac{(A-a)^2}{A}\right\}$ or as we may write them μAR^2 and $\mu_1 A(1-R^2)$, where $R=1-\frac{a}{A}$. If the operation be repeated n times the residual whiteness will become μAR_n and the redness will become $\mu_1 A(1-R^n)$. If n becomes infinite the whiteness vanishes and the red becomes $\mu_1 A$, being the red light that would be given off if we supposed the surface to be covered with red points only.

A method for experimentally testing the foregoing theory relative to the intensity of the residual whiteness, after admixture with a perfect black, would be as follows. Take three surfaces of different degrees of whiteness (A, B, C), due to admixture with p, q, r units of black; look at the surfaces through some fluid containing in solution some soluble black substance, adjust the columns so that the intensity of the transmitted light shall be the same.

Suppose first we compare A and B. Let t and t^1 be the lengths of the columns. Then

$$W_0R^hk^t = W_0R^qk^{t'} \ldots\ldots\ldots\ldots\ldots\ldots (1).$$

Now compare B with C, whence, if θ and θ^1 be the lengths of the columns, we shall have

$$W_0R^qk^\theta = W_0R^rk\theta^1 \ldots\ldots\ldots\ldots\ldots (2)$$

From equations (1) we have $R = k^{\frac{t^1-t}{p-q}}$

and from equation (2) we have $R = k^{\frac{\theta^1-\theta}{q-r}}$

but these two values of R ought to be the same, so we ought to have the equation.

$$\frac{t^1-t}{p-q} = \frac{\theta^1-\theta}{q-r}$$

The different tints I used consisted of $BaSO_4$ and lamp black. Tint A consisted of lamp black 0·012 grms. $BaSO_4$ 10 grms. Tint B contained twice the above quantity of lamp black to the same quantity of $BaSO_4$, and tint C contained four times the quantity of lamp black to the same quantity of $BaSO_4$. The absorbing medium I used consisted of water containing a minute quantity of lamp black in suspension. This, as I have before shown, behaves nearly the same with regard to the absorption of light as if the carbon were in solution.

A comparison of tint A with tint B gave $R=k^{\cdot 3}$. Tint A compared with tint C gave $R=k^{\cdot 346}$. Tint B compared with C gave $R=^{\cdot 4}$. Inasmuch as k is a fraction, these three values of R will not differ much. The experimental enquiry is difficult, and the following defect is likely to have some influence on the result. The grey powders were mixed with a few drops of water and pieces of cardboard covered with the paint so obtained, and then dried. But if we take an intimate mixture of two powders, and make it into a paint with oil or water, the gravity of the two powders being different, and the fluid medium imparting a certain degree of mobility to the particles, there will be a tendency for the lightest powder to come to the surface. I have sometimes noticed, with regard to the tablets prepared as above, that portions which had been rubbed seemed perceptibly lighter than the undisturbed portion; possibly this may be due to a slight excess of carbon on the upper surface.

I also compared tint A with another consisting of 0·4003 grams carbon to 10 grams $BaSO_4$, thus the quantity of carbon is a considerable multiple of that contained in tint A. The value of R got from the comparison differed considerably from a value of R which I got by comparing A with B. At first I thought this was due to a failure in the theory; after some time it occurred to me that the conditions of my experiments were not the same as the conditions of the theory. In the theory, I had supposed that the white was mixed with a perfect black, in the experiments the white had been mixed with a grey.

Those surfaces which are popularly known as black, are in reality not black but grey. If we take such a surface, whether of black velvet or lamp black, aud hold an opaque object before it so as to intercept a portion of the incident light, a shadow will be found on the surface; but it is evident that a perfect black is incapable of receiving a shadow. Also, when I looked at a surface of lamp black through the colorimeter (consisting of a glass cylinder covered with black cloth, except a small aperture at the bottom) the lamp black surface appeared grey. The formula for the intensity of the residual whiteness, if we mix with grey, will not be the same as if we mixed with black. The formula will have to be altered as follows: suppose W_0 the initial whiteness, after the addition of perfect black the residual whiteness will be W_0R^n, but if the material added be grey, we must give back a quantity of white, which will be some fraction of the whiteness lost. Suppose p to be this fraction; also the whiteness lost will be $W_0 - W_0R^n$; so the quantity of white to be restored will be $W_0p(1-R^n)$ and the total whiteness will be $W_0R^n(1-p)+W_0p$. If we suppose n to become infinite the whiteness becomes W_0p, being the whiteness or greyness of the so-called black body. We might also have deduced the formula as follows: take a white area A, then the quantity of white light given off we may denote, by μA; now let a series of grey points to fall upon this, let a be the area of the spots, then the quantity of white light given off by this we may denote by $\mu_1 a$, the uncovered white area will be $A-a$, and the quantity of white light given off by this will be $\mu(A-a)$, therefore the whole quantity of white light will be $\mu(A-a)+\mu_1 a$, or $\mu AR+\mu_1 a$ if R be written for $1-\frac{a}{A}$. If we suppose another series of grey points distributed over the surface, the uncovered white area will be AR^2, and the surface covered by the grey points will be $A-AR^2$, so that the quantity of light will be $\mu AR^2+\mu_1(A-AR)^2$. If the operation be repeated n times the expression for the residual whiteness will be $\mu AR^n+\mu^1(A-AR^n)$ which may be written in the form $\mu A(R^n(1-p)+p)$, when $p=\frac{\mu_1}{\mu}$, also $\mu A=W_0$, the initial whiteness so that the expression is equivalent to the one previously given.

On the Theory of Engraving.

Another subject of interest in Colorimetry is the theory of engraving, which I think has never been considered. In this art various shades of grey are given to white surfaces by aggregations of lines or dots, giving rise to line, mezzotint, and other varieties of engraving. If the tint be produced by lines, it may be estimated as follows. Take a white square area A and rule it with parallel lines. The quantity of white light given off initially we may denote by μA. Let b be the breadth of one of these lines and l its length; also suppose that then an n of these lines, then the white area uncovered will be $A-nbl$. Suppose n to become very great and b very small, so that we no longer have the impression of black lines on a white surface, but see a uniform grey surface, then the expression for its degree of whiteness will be $\mu(A—nbl)$ or $W_0(1—nr)$ if r denote $\frac{bl}{A}$

Sometimes an engraver, instead of using parallel lines only, crosses the lines (cross hatching). With a given number of lines the tint will not be the same if he draws them all parallel, and if half are drawn at right angles to the others. Suppose we have $2n$ lines, if drawn parallel the degree of whiteness will be $W_0(1-2nr)$, but let n of these lines be drawn perpendicular to the remaining n. Take the case of one of these perpendiculars, it will intersect one of the first series in a square whose area is b^2, and as it is cut by n lines the sum of these will be nb^2; the additional white area, blotted out by this line, will be $lb-nb^2$, and since there are n such lines the total area they blacken will be $n(lb-nb^2)$. Hence the remaining white area will be $A-nlb-(nlb-nb^2$, which may be written $A(1-nr)^2$, since $l^2=A$. If W_1 denote the whiteness when the lines are parallel, and W_2 when they cross, we shall have

$$\frac{W_1}{W_2}=\frac{1-2nr}{(1-nr)^2}$$

In both cases the lines are supposed to be so thin as to be individually imperceptible.

Again, suppose an engraver to cover a square white area with black circular spots which touch one another, the spots being very numerous and individually imperceptible, so that we receive the impression of a grey surface. If beyond this stage he exercised his skill in diminishing the area of the spots infinitesimally, and increasing their number, so that they still fulfil the condition of touching, it will make no difference in the intensity of the tint: for the area of the spots is always the same, and equal to that of the circle that can be inscribed in the square.

"The Antiquity of Toughened Glass," by WILLIAM E. A. AXON, M.R.S.L., F.S.S.

The toughened glass of modern times appears to have been anticipated in imperial Rome. Inventors have never been very well treated, but the peculiar fashion of rewarding mechanical and scientific skill, then employed, has fortunately found no parallel in modern days. That the secret of rendering glass hard had been discovered some 1800 years before the patent of M. de la Bastie appears probable from the following passage in the well known work of Pancirollus.

"It is reported, that in the time of *Tiberius* there was glass found out so rarely temper'd that it might be made *ductile* and flexible like paper, and also that the author of this invention was put to death, because having repair'd at *Rome* a magnificent palace that was ready to fall, and being paid by *Tiberius*, and forbidden to come any more in his sight, he having found out the way of making glass *malleable*, came again into his presence to shew his art, expecting from the Emperor (as *Dio* writes) a great reward.

"But *Pliny* tells us in the 26th chapter of his 36th book that the whole shop of this artist was ruinated and demolished, to prevent the lessening and bringing down the *price* of silver and gold. Some think it was done by the *malice* of *Tiberius*, who had no kindness for virtuous and ingenious men.

"That which our author saith concerning this artizan, *Dio* relates (in the 27th book of his history) after this manner, who tells us that when the great *Portico* at *Rome lean'd* all on one side, it was after a wonderful manner set *upright* again; for a certain *Architect*, (his name is not known, for *Tiberius* so envy'd his art that he forbad it to be register'd) having so fixed the foundations as to render them immoveable, did, by the strength and force of men and engines, restore it again to its former posture.

"*Tiberius* wondered at the thing, and so much *envy'd* the artist, that after he had *rewarded* him he *banished* him the City. But coming afterward again to the Prince, he threw away a glass on purpose, and brake it, and then took it up again and made it as whole as ever, hoping thereby to obtain his pardon; but he missed his aim, being presently commanded to be put to death.

"*Petronius* tells us that there was a certain *Smith* that made *Vessels* of *glass* as strong and durable as those that were made of *gold* and *silver*, wherefore having made a *vial* of the same materials, very fine and curious, he presents it to *Tiberius*. The *gift* is commended, the *artist* admir'd, the *devotion* of the donor is kindly accepted.

"And now the *Smith* to turn the *wonder* of the spectators into astonishment and amazement and the better to recommend himself to the Prince's favour, took a glass *vial* and dash'd it against the pavement with all his might, so that if it had been brass it must needs have been broken. *Cæsar* did not so much *wonder* as *fear* at the fact. The *Smith* took up the *vial*, not broken, but bruis'd a little, as if it had been some *metal* in the form of *glass*, and afterward he mended it with a hammer, as if it had been some *tinker* cobling a piece of *brass*. When he had done this *miraculous* piece of work the man was puffed up into such a conceit of himself that he presently fancy'd that he should be snatched into heaven, and should converse with no less than *Jupiter* himself, in regard he gain'd the smiles of the Emperour, and had deserv'd (as he imagined) the applause of all. But it fell out otherwise, for *Cæsar* enquiring whether anybody else knew the art beside him, and being answered No, commanded this fellow to be immediately beheaded, alledging that if this *skill* and ingenuity was rewarded and encourag'd it would bring down the price of *gold* and *silver*, and make those metals as vile as dirt."

In a footnote we read as to lessening *the Value of Gold*,

"For the use of *drinking*, glasses hath banish'd *gold* and *silver* almost quite out of doors, and therefore the Emperour *Gallienus* could not endure the sight of glass, saying, *there was nothing in the world more vile and common.*"—(*The History of many Memorable Things Lost which were in use among the Ancients*, by Guido Pancirollus. [English translation.] London, 1715.)

The story of the inventive artizan was popular during the middle ages, and is given in "Gesta Romanorum." Allowing for the fashion of telling the tale, we appear to have here an ancient anticipation of modern invention on the toughened glass, which however has not yet caused that depreciation of gold and silver, deprecated in so sanguinary a manner by Tiberius.

Ordinary Meeting, October 19th, 1880.

E. W. BINNEY, F.R.S., F.G.S., President, in the Chair.

The following communication from Dr. R. ANGUS SMITH, F.R.S., was read :—

In relation to my paper on the word Chemia, Mr. Wm. Simpson informs me that Dr. Muir, in "Sanscrit Texts," vol. 5, p. 402, refers to the Rig Veda, where Kam is represented as Eros. Dr. Muir also says that Kama is distinctly identified with Agni, the Sanscrit for fire. This gives the word a firmer basis in the East than I found for it. He also adds that Wilford, in "Asiatic Researches," identifies Cæma or Kama of India with the Chemia or Chemi of Egypt. I shall add this to my paper, which is being printed in full. It is one of the proofs of early connection of Aryan and Semitic people both in language and thought; but this is a subject that belongs to others to speak of. I hear of other connections with the far East in the word Chemia, but having begun to argue this view of the case, others may advance it. When I say begun, I merely sought to connect old links of thought, and other old links may be found lying about in many places.

"Additional Note on a Theory of Mixed Opaque Colours," by JAMES BOTTOMLEY, D.Sc.

At the last meeting of the Society I read a paper on a theory of mixed opaque colours. One of the problems considered was the mixture of black with white. The problem seemed to me to have some analogy with sprinkling small black spots on a white surface so as to yield a grey tint. I obtained a formula $Wn = W o R^n$, Wn denoting the residual whiteness after n repetitions of the operation.

In the discussion which followed it was suggested by Mr. Heelis that some of the spots might be superimposed on others in the same unit. This will leave the expression for Wn unaltered in form, but will introduce a new value for the constant. The symbol R stands for $1-\frac{a}{A}$, A being the area of the white surface and a the surface occupied by the mass of black. The problem under consideration is a physical one, and ultimately the spots will be due to the atoms of matter; these are finite in magnitude. Let ρ be the area covered by an atom of matter, and suppose our unit of mass to contain p atoms—let these be thrown down singly on the surface; then the remaining whiteness after the expenditure of the unit will be $Wo\left(1-\frac{\rho}{A}\right)^p$ If we throw down n units the remaining whiteness will be $Wo\left(1-\frac{\rho}{A}\right)^{n}$ This then will be a strict solution of the problem, for manifestly one particle cannot be superimposed on itself. If we keep to the same unit of mass and the same kind of matter, we may write R for $\left(1-\frac{\rho}{A}\right)^p$ so that the expression for the residual whiteness may be written WoR^n, being the same in form as that given before.

We may also write our first expression in the form

$$Wn=Wo\varepsilon^{-\log\left(1-\frac{a}{A}\right)n}$$

or if we expand the logarithm

$$Wn=Wo\varepsilon^{\left(-\frac{a}{A}-\frac{a^2}{2A^2}-\&c.\right)n}$$

on a particular hypothesis a simple expression may be obtained for the residual whiteness due to the distribution of a given quantity of matter over a surface. Suppose that a can vanish and n become indefinitely great, the first term in the index is $-\frac{a}{A}$. Hence this multiplied by n would tend towards the ambiguous form $\frac{o\infty}{A}$; but the limit of the numerator will be the quantity of black employed, which we may denote by b, so that the first term would become $-\frac{b}{A}$. The second term multiplied by n may be written in the form $na\frac{a}{2A^2}$, the limiting value of na is b, so that this term becomes $\frac{ba}{2A^2}$; since it contains a term which ultimately vanishes it will disappear, so *a fortiori* all the remaining terms. So that we should get as the residual white area $A\varepsilon^{-\frac{b}{A}}$

This simple form of expression for the white area has been suggested by Mr. James Heelis in a letter to me. The atomic constitution of matter seems a bar to its perfect acceptance. It does not seem likely that we can so divide matter as to arrive at 0. In this, as in many problems, physical conditions place limits to mathematical generalities. Nevertheless, on account of the extreme smallness of atoms there will be no sensible difference whether we use this formula or the one suggested by me, which takes into account the atomic constitution of matter, for in the term

$$\varepsilon^{-\frac{pn\rho}{A}-\frac{pn\rho^2}{2A^2}-\&c.}$$

the second term of the expansion = first term $\times\frac{\rho}{2A}$ This will be so small as not to be sensible, and may therefore be neglected—and so, *a fortiori*, the remaining terms. The above remarks will apply to the mixtures of other colours as well as black and white.

"On some early anticipations of Heliographic Signalling," by WILLIAM E. A. AXON, M.R.S.L.

The use of the heliograph in war is likely to gain ground. *Nature* (April 29, 1880, vol. xxi., p. 617) gives an instance in which a message was flashed by this means as speedily as by the electric telegraph. The following description is given of the modus operandi: "The line of communication cannot be cut, for the simple reason that the signalling takes place over the heads of the enemy, and the stations required are but few and far between. A 10-inch mirror—and this is the diameter of the ordinary field heliograph—is capable of reflecting the sun's rays in the form of a bright spot, or flare, to a distance of fifty miles, the signal at this interval being recognisable without the aid of a glass. That is to say, two trained sappers, each provided with a mirror, can readily speak to one another, supposing the sun is shining, with an interval of fifty miles between them, provided their stations are sufficiently high and no rising ground intervene to stop the rays.

Professor REYNOLDS, F.R.S., said that he had been able to get a barometer tube free from air by first washing the tube with water, and introducing the mercury while the tube was wet, and then leaving the tube in an inverted position for several days. The water absorbed the air, and floating up between the mercury and the glass left the tube dry, full of mercury, and free from air. He hoped at the next meeting to report some further experiments on the suspension of mercury by its cohesion in a tube 90 inches long.

"On some Marine Fossil Shells in the Middle Coal Measures of Lancashire."

The PRESIDENT said that Mr. George Wild, of the Bardsley Collieries, near Ashton-under-Lyne, had lately informed him of some very interesting fossil shells having been met with in sinking the deep pit at Ashton Moss, which has now reached the great depth of about 800 yards.

In the Lancashire, Cheshire, Staffordshire, North Wales, Yorkshire, and Derbyshire Lower Coal Measures it has been long known that certain beds of marine shells of the genera

Nautilus Goniatites, Aviculopecten, Lingula, &c., were met with, but they were supposed not to extend upwards into the Middle Coal Measures. However, about ten years since, Professor Green, M.A., F.G.S., of the Yorkshire College of Science, then on the Geological Survey, found some of these shells in the bed of the Tame, under the Guide Bridge railway viaduct at Dukinfield, and he supposed them to lie about 150 yards above the Big Mine of Ashton. As no evidence of superposition could then be obtained, doubts were entertained as to their true geological position, some parties thinking that they might belong to the Lower Coal Measures, and there thrown down by a fault.

In 1861 he (the President) examined the beds and procured specimens of *Nautilus, Goniatites, Discites, Aviculopecten, Orthoceratites,* and *Posidonia,* but he could find no clear evidence of their true position in the Coal Measures, although they certainly looked more like Middle than Lower.

In the memoirs of the Geological Survey of Great Britain on the country around Oldham, published in 1864, the late Mr. Salter, A.L.S. and F.G.S., describes Professor Green's shells under the names *Aviculopecten fibrillosus, Clenodonto* sp. inc., *Goniatites* sp. inc., *Nautilus præcox, Discites rotifer,* and *Discites* spec. unc.

Last week he (the President) went over to the Ashton Moss Pit, and in the spoil on the pit hill succeeded in finding specimens of *Goniatites, Posidonia, Lingula Mytiloides,* and *Sanguinolites costellatus.* The specimens, especially the *Goniatites,* were all of small size when compared with those generally found in the lower coal measures. According to Messrs. Higson, the mining engineers, the bed of shale wherein the fossils occurred is somewhere about 130 yards above the Big Mine, thus clearly proving that there is a bed of marine shells in the upper part of the middle coal measures. It also seems probable that the bed in which the fossils are met with at Ashton Moss pit is the same, or one lying near to it, as that discovered by Prof. Green, above the Big Mine of Dukinfield, and that the strata seen in the Tame lie pretty regular between the two places, and have not been much disturbed by faults.

"Some endeavours to ascertain the nature of the insoluble form of Soda existing in the residue left on Causticising Sodium Carbonate with Lime," by WATSON SMITH, F.C.S., Assistant Lecturer on Chemistry in the Owens College, and Mr. W. T. LIDDLE.

In the following are given the results of an inquiry (yet in progress), which were obtained towards the close of last session, in the Laboratory of Owens College, by Mr. W. T. Liddle in conjunction with myself, and with the occasional co-operation of Mr. H. Rimmer. The present inquiry was the final step after a series of exercises in the technical examination of some alkali products by the two gentlemen named, kindly furnished by Messrs. Gaskell, Deakin, & Co.

Hargreaves (Chem. News, 387) and Kynaston (Chem. Soc. J., 11, 135) have noticed the occurrence of soda in an insoluble form in the crude soda (black ash) of the alkali works, but they only speak of alumino-silicates and silicates of sodium, and in these early papers mentioned don't appear to imagine any other insoluble compound present in which soda may be practically lost to the manufacturer.

Dr. G. R. A. Wright published a paper (appearing in Journ. Chem. Soc., year 1867, p. 407) in which he distinctly shows (1) that soda in an insoluble form does exist in black ash treated with water, in process of lixiviation, and (2) that though it may partly exist as alumino-silicate, yet undoubtedly it exists in some other form, and most probably as a double sodium calcium carbonate.

To show the importance to the soda manufacturer of this loss in insoluble sodium compounds left behind in the black ash and waste, Wright states that it forms the largest item of the several individual losses, making up the total 20·24 per cent loss out of 100 parts Na_2O as salt cake occurring in the practical conversion of salt cake to soda ash. Wright tabulates this as follows:

Previous to lixiviation of the black ash.	
Undecomposed sodium sulphate	3·49
Insoluble sodium compounds	5·44
Vaporisation, &c., of sodium compounds	1·14
During and after lixiviation.	
Soluble alkali left in vat waste	3·61
Leakage and losses in soda ash process...	6·56
Total loss per cent.........	20·24

In experiments tried with samples of black ash Wright showed that on prolonged boiling (6 hours) with water, the insoluble sodium compound in the black ash residue was decomposed, and yielded a sodium salt in solution capable of neutralising acid. On taking soda waste and submitting this to prolonged boiling with water, only 3·81 out of 5·08 per cent of the insoluble soda, calculated as Na_2CO_3, were extractible, and he considers that this difference from his experience with the black ash, is due to the influence of the other sodium salts present on the insoluble compound in the case of the black ash. Wright also cites the well known fact, that on causticising sodium carbonate solutions with quicklime, the calcium carbonate formed retains a considerable portion of sodium in an insoluble form, and adds, that most probably in the case of the black ash a double sodium calcium carbonate is formed, either in the furnace or on addition of water to the crude soda. In further proof of this view he mentions the case of some experimental charges for black ash, in which an unusual excess of limestone was used. Wright examined the resulting product to see if more of this insoluble compound were formed, and found there was.

Mactear (Chem. News, Feb. 2, 1872, p. 55) makes the interesting discovery that "oxidised alkali waste yields on lixiviation almost all the soda contained in the waste." The soda thus rendered soluble occurs in the solution as sulphate. Mactear says "The chief loss in the soda process is that which occurs during lixiviation of the ball soda. This loss is in part represented by the insoluble and soluble compounds left in the waste. The former sometimes amounts to 3 or 4 per cent of the soda, and the amount is increased as the silica and alumina of the raw materials increase."

Wright has shown that an increase of limestone in the black ash mixture will also increase the amount of the insoluble soda compound.

Scheurer-Kestner (Comptes Rendus, Nov. 11, 1872) confirms Wright's views. He proves conclusively that an increase of chalk in the black ash mixture causes a proportionate increase in the amount of insoluble soda compounds left in the waste. "The excess of chalk employed is converted into lime, and when the crude soda is lixiviated with water, the lime while becoming hydrated reacts upon the sodium carbonate and thereby renders a portion insoluble in water." According to Scheurer-Kestner's experiments, the lime may retain even as much as from 4·75 to 4·95 per cent of soda Na_2O.

With regard to our own experiments, we first operated upon some samples of soda waste, with the view of determining the soluble and insoluble soda therein contained.

After titration and digestion with water of about 60°, for an hour, a sample of waste yielded us 0·22 per cent of alkali as Na_2O soluble in water. On solution of the residue in acid, a gravimetric determination of the residual and therefore insoluble soda gave 2·18 per cent Na_2O, hence the waste contained of total Na_2O—2·40 per cent.

Another sample analysed by Mr. Rimmer gave as

soluble Na_2O—	0·31	per cent.
insoluble „	1·91	„
Total	2·22	„

Wright found in an average sample of a fortnight's soda waste as

soluble Na_2O—	2·07	per cent.
insoluble „	0·91	„
Total	2·98	„

In the difference noticeable between Wright's results and ours, as regards the insoluble soda, it is possible his own explanation for the fact that continuous boiling with water will extract the insoluble soda from black ash, but will not from soda waste, may here hold good, for it will be noticed his soda waste contains considerably more soluble sodium salt than ours does.

We now turned our attention to the soda left behind in the lime sludge remaining as a residue, in the process of causticising sodium carbonate solutions. In the sludge taken as a sample of many tons lying outside the causticising plant of a works, after suitable draining, the total Na_2O extractible by water was found to be 2·62 per cent. Calculated roughly into dry residues this would represent 3·84 per cent.

Now according to several careful analyses made some years ago, the amount of soda existing in lime mud in the insoluble form averages about 2½ to 3 per cent on the mud. If we add this to the above figure 2·63 per cent for the soda soluble in water, we get an approximate 5 per cent of total soda. In alkali works where black ash is made, this soda is not lost, the mud, drained and dried as far as possible, being mixed with the black ash charges, and worked into ball soda, and thus it is kept in constant circulation, instead of being lost. The loss entailed thereby is one of heat, and hence of fuel, in converting water into steam in the black ash furnace.

In order to have some object to aim at, we commenced the next step by assuming the existence of such a double sodium calcium carbonate, as Wright believes is formed, under the circumstances already named; and, as the simplest mode of representing such a compound, we took the liberty of giving it the formula

$$Ca\left\langle\begin{matrix} CO_3Na \\ \\ CO_3Na \end{matrix}\right.$$

We then made an attempt to prepare this so far hypothetical salt. But before proceeding to this, we will just refer to some experiments we made with the object of ascertaining with some degree of precision under what circumstances the insoluble sodium compound is formed.

Solutions of caustic soda and sodium carbonate were prepared; the former had a specific gravity of 1·09 and contained 6·52 per cent Na_2O; the latter contained 5·985 per cent Na_2O.

(I.) A quantity of precipitated $CaCO_3$ was diffused in water and boiled then with 20 c.c. of standard caustic soda for 15 minutes. After filtering and washing till the filtrate was no longer alkaline, it was found by titration with normal hydrochloric acid that no soda had been retained by the calcium carbonate.

(II.) No soda was retained either, when instead of the precipitated $CaCO_3$, finely powdered marble was used.

(III.) A quantity of calcium carbonate (precipitated) was now boiled for a long time with 20 c.c. of the sodium carbonate solution of known strength and with the addition of water. No soda was retained.

(IV.) The above experiment was repeated with finely powdered marble, with like negative results.

(V.) A quantity of milk of lime was now taken, and boiled with 25 c.c. of the Na_2CO_3 solution. After filtering, washed with 500 c.c. of hot water, removed lime, filtered, washed, evaporated to dryness, ignited, dissolved in water, and titrated, 1·286 per cent Na_2O was retained by the calcium residue.

(VI.) A quantity of milk of lime taken, and to it were added 25 c.c. of caustic soda solution with some water. The whole was boiled for some time—0·05 per cent Na_2O retained. Some of the sodium hydrade becoming accidentally carbonated might account for this.

This lime mud residue of (V), washed as above till the filtrate ceased completely to react alkaline, was washed into a flask and a current of CO_2 was passed through for a long time, to endeavour to decompose this insoluble compound. In this way only 0·078 per cent of the soda (Na_2O) was extracted.

We now attempted to prepare some of the double sodium calcium carbonate in the following manner :—

A quantity of pure sodium carbonate solution (somewhat concentrated) was mixed with about three times its volume of clear lime water, and this mixture was heated to boiling. The precipitate was allowed to settle, was filtered, and washed with hot water till the filtrate ceased to manifest the slightest alkalinity to test paper. It was then dried in the water bath. When the lime water was added to the sodium carbonate solution, the precipitate of carbonate which came down had the floccular appearance of alumina freshly precipitated, but on standing for about half an hour without heating, it became crystalline in appearance. The dried precipitate under the microscope was distinctly crystalline, being apparently composed of minute rhombohedra.

In subsequent experiments we found the microscopic appearance to vary, sometimes rhombohedra mixed with minute prisms making their appearance.

On analysis we found that the crystalline powders (they were only just perceptibly crystalline to the naked eye) contained according to two experiments:—

$$\overbrace{\begin{matrix}(1) & & (2)\\ 97\cdot65\% & \ldots & 97\cdot90\%\end{matrix}}^{CaCO_3} \qquad \overbrace{\quad 2\cdot46\% \quad}^{Na_2CO_3}$$

It would seem probable from this that the major reaction, so to say, is that converting sodium carbonate into hydrate, calcium hydrate passing into *pro ratâ* carbonate, but a minor reaction also occurs by which a small quantity of a double carbonate is formed. It is all the more certain that such a compound actually is formed from the fact that the precipitates obtained as just mentioned (and this experiment has been repeated many times) were in every case distinctly crystalline powders; we never detected the smallest amorphous particle with the microscope. Now it is hard to imagine any difficulty in removing sodium carbonate by continued washing with boiling water in excess, from a powder consisting of distinct crystals of calcium carbonate. We can then best account for the presence of the alkali by considering it as having formed itself, a crystalline and insoluble compound with calcium carbonate, this double crystalline carbonate being mixed in small quantity with the superabundant calcium carbonate.

Another experiment was now tried, to prove indirectly if such a double carbonate were present in the crystalline precipitated powders we obtained as already described. We reasoned thus: "If such a double compound exist here, strong ignition ought to decompose it, driving off carbon dioxide from the lime, but leaving sodium carbonate intact," thus

$$Ca \begin{matrix} \diagup CO_2ONa \\ \diagdown CO_2ONa \end{matrix} = CaO + Na_2CO_3 + CO_2$$

This experiment was tried with a small quantity of the crystalline precipitate. It was well ignited in a platinum crucible, and the resulting mass was treated with some dilute alcohol, which extracted easily a quantity of the soda, showing a strongly alkaline reaction to test paper. We intend to repeat this experiment quantitatively, and to determine thus the amount of soda extracted.

One point becomes pretty clear by these experiments, viz. that the materials lime and sodium carbonate in contact with water give rise to the formation of this insoluble sodium compound. Also that it is not a case of mere cohesive retention of soda by the lime mud, for our experiments show that until a definite and suitable chemical reaction between the members of the mixture sets in, no appreciable amount of soda is retained, but that when such reaction sets in, in the condition of nascent state and therefore unstable equilibrium, in which the various constituents momentarily find themselves, a major and normal reaction takes place, and also this minor reaction to a small extent—giving us a small yield of the insoluble sodium compound.

The experiments we have yet in view with the crystalline precipitate prepared as mentioned, and also with ordinary lime mud, are (1) the effect of long boiling with water to see if thus the insoluble compound is decomposed, as with

Wright in the case of black-ash; (2) boiling with water containing certain salts in solution, such, *e.g.*, as sodium sulphide. We hope by obtaining a closer knowledge, at all events, of the properties and behaviour of this singular compound, to find at length, peradventure, a practical and ready means for extracting it, and thus doing a service to the alkali manufacturer.

Ordinary Meeting, November 2nd, 1880.

Edward Schunck, Ph.D., F.R.S., V.P., in the Chair.

"On the Conditions of the Motion of a portion of Fluid in the manner of a Rigid Body," by R. F. Gwyther, M.A.

The condition that a portion of fluid may comport itself as a rigid body, or that fluid may remain in a state of relative rest upon or within a moving solid, has not, as far as I am aware, been mathematically investigated. We know, however, that in certain cases, as on the surface of the earth, the condition can be realised, or that any deviation has not been discovered by undirected investigation.

In the case considered, the velocity at points in the fluid must consist of a common linear velocity, and a common angular velocity about some axis, moving or fixed. Therefore, using the quaternion notation, the velocity must be of the form

$$\sigma = \Sigma + V\epsilon\tau,$$

where Σ is the common linear velocity, ϵ the vector axis of instantaneous rotation, and τ the vector of any point in the fluid.

The equation of motion is

$$D t\sigma + \frac{1}{\rho}\nabla p = a \text{ ....}(1)$$

a denoting the force acting on the element of the fluid, p and ρ having the usual meanings. Under the condition stipulated no viscosity is called into action.

If ρ be a function of p only, we may write

$$\frac{1}{\rho}\nabla p = \nabla P.$$

Substituting the required form of σ we get

$$\dot{\Sigma} + V\dot{\epsilon}\tau + 2V\epsilon(\Sigma + V\epsilon\tau) = a - \nabla P \text{ ....}(2)$$

Now act upon this with ∇ (which will not affect either Σ or ϵ) and afterwards take the vector and scalar parts, thus:

$$\nabla(\mathrm{V}\epsilon\dot{\tau} + 2\epsilon^2\tau - 2\epsilon\mathrm{S}\epsilon\tau) = \nabla a - \nabla^2\mathrm{P}$$

$$\text{or } 2\dot{\epsilon} = 4\epsilon^2 = \nabla a - \nabla^2.\mathrm{P}$$

$$\therefore\ 2\dot{\epsilon} = \mathrm{V}\nabla a \text{ and } 4\epsilon^2 = \nabla^2\mathrm{P} - \mathrm{S}\nabla a \ \ldots\ldots\ldots\ldots\ldots(3)$$

The first of these equations gives the required condition; if the forces acting are conservative $\mathrm{V}\nabla a=0$, and ϵ must be constant in direction and magnitude—the magnitude and pressure being connected by the second equation. The case here considered is the general case of the possibility of a quantity of dead water accompanying a moving solid, and includes that of fluids in relative rest upon or within the earth.

Considering the possibility of a fluid interior of the earth, it must be observed that, owing to precession and nutation, the axis of the earth is not constant in direction, and that therefore the condition is not truly satisfied. If however the shape of the earth gives a stable form for the fluid, the viscosity of the fluid will tend to mitigate any departure from the apparent rigidity, after such motion has once been established.

Precession must also prevent the absolute rest of fluid contained in a vessel upon the earth's surface, and it is possible, though highly improbable, that in this way precession might be demonstrated, as Foucault's pendulum demonstrates the earth's rotation.

"Did Pascal invent the Wheelbarrow?" by WILLIAM E. A. AXON, M.R.S.L.

The recent celebrations in honour of Pascal brought up once more a curious claim that has been advanced on his behalf as the inventor of the wheelbarrow. The statement has been made by Jules Janin and other writers, but the assertion is purely traditional and has no historic basis.

That the wheelbarrow was known long before the days of Pascal may be seen by anyone who will examine the curious engravings in Georgii Agricolæ de re metallica (Basileæ, 1556). In this impressive folio, which may be seen at the Manchester Public Library, there are several pictures in which miners are represented as transporting minerals from place to place in wheelbarrows. A writer in *La Liberté* states that he pointed out this work to Janin, who replied with characteristic indifference: "Cela m'est bien égal, ce n'est pas moi qui ai inventé cela, je l'ai lu, j'en laisse la responsabilité à ceux qui l'ont écrit avant moi, et n'écrirais pas une ligne pour le contredire." This shows a spirit unworthy of the true antiquary, to whom truth, even in trifles, is sacred, and who does not readily admit the existence of trifles. A much earlier instance of the use of the wheelbarrow can be cited. In the mural paintings at Gawsworth in Cheshire, discovered in 1851 and since destroyed, there was a representation of the Doom or Last Judgment, in which one of the demons is seen carrying a lost soul on a wheelbarrow to the mouth of hell. In form the barrow resembles those which are still used on the moss near Gawsworth.*

The Church is held by Mr. J. P. Earwaker to have been erected in the fourteenth or fifteenth century. We have thus the certain fact that the wheelbarrow was known not only in German mines but in a remote agricultural district of England, one hundred years before the time of Pascal.

"On the History of the artificial Preparation of Indigo," by Carl Schorlemmer, F.R.S.

One of the most brilliant discoveries which lately has been made is that of the synthesis of indigo, the Indian colour, which is mentioned by Dioskorides and Pliny, as well as by the Arabians. It was however only after the

* Historical and Antiquarian Notes on Gawsworth Church, by Joseph F. A. Lynch. Manchester, 1879, p. 25.

discovery of the sea passage to India that it became generally known in Europe; but its use as a dye was greatly retarded by the opposition it met with from the large vested interests of the cultivators of woad, *isatis tinctoria*, the European indigo-plant. The English, French, and several German governments were induced by the growers of woad to promulgate severe enactments against it. Thus Henry IV. of France issued an edict condemning to death anyone who used that pernicious drug called "devil's food." The employment of woad was however gradually superseded by that of indigo, and as soon as organic chemistry had advanced far enough, chemists began to examine this important colouring matter, which was first obtained in the pure state by O'Brien, who states in his treatise "On Calico Printing," 1789, that on heating indigo the colouring matter volatilises, forming a purple vapour, which condenses as a blue powder, whilst the impurities of the commercial product are left behind. Indigo-blue, or indigotin as the pure compound is called, was afterwards analysed by several chemists, who found that its most simple formula is C_8H_5NO, which was subsequently doubled for several reasons.

The literature of the chemistry of indigo is very large; of the numerous researches, I can here mention only those bearing directly on my subject.

In 1840, Fritzsche found that on distilling indigo with potash a basic oil is produced, which he called *aniline* $C_6H_5.NH_2$ from anil, 'by which name the Portuguese introduced indigo first into Europe. The word is Arabic, and means simply, the blue.' In the following year he obtained by boiling indigo with caustic soda solution and manganese peroxide a compound which he called anthranilic acid, and which, now known as *orthamidobenzoic acid* $C_6H_4(NH_2)$ CO_2H. He also observed that by heat it is resolved into aniline and carbon dioxide.

At about the same time Erdmann and Laurent independently studied the action of oxidising agents on indigo and obtained *isatin*, $C_8H_5NO_2$ which is not a colouring matter. The further examination of this body led to most interesting results, but as those are not directly connected with the subject of this paper, I cannot discuss them here.

We must therefore proceed at once to 1865, when Baeyer and Knop found that by acting on isatin in an alkaline solution with hydrogen in the nascent state it is converted into a yellow crystalline body, which they called *dioxindol* $C_8H_7NO_2$. This is easily further reduced in an acid solution to *oxindol*, C_8H_7NO, which forms colourless needles, and on its vapour being passed over red-hot zinc-dust it loses its oxygen, *indol*, C_8H_7N being formed, which is also a colourless crystalline compound and a most interesting body, inasmuch as it is also formed, as Nencki and Kühne have shown, in pancreatic digestion, and is contained in the fæces.

In 1869, Baeyer and Emmerling obtained indol from cinnamic acid, which occurs in several plants, and can be obtained artificially from coal-tar, as I shall show further on. By the action of nitric acid it yields two isomeric nitro-compounds; one of them, called orthonitro-cinnamic acid, loses, when heated with caustic potash and iron filings, carbon dioxide, and oxygen and indol is formed:

$$C_8H_6(NO_2)CO_2H = C_8H_7N + O_2 + CO_2$$

The same chemists discovered, 1870, a method by which isatin can again be reduced to indigo-blue. By heating it with a mixture of phosphorus trichloride, acetyl chloride, and phosphorus to 70—80°, they obtained a green liquid which, when poured into water, deposited, on standing exposed to the air, a blue powder containing indigotin. At the same time a purple colouring matter was formed, which they called indigo-purpurin.

It has been known for some time that urine, on standing, sometimes deposits indigo-blue. Jaffé, in 1870, found that he could produce it by the subcutaneous injection of indol;

and Nencki, who confirmed this observation in 1875, was able to convert indol into indigotin by the action of ozonised air. But the yield is only very small, as the colouring matter readily undergoes further oxidation.

However, the synthesis of indigo was thus completed, because indol can be built up from its elements; but chemists were not satisfied with it, the method being neither a practical one nor giving any clue as to the chemical constitution of indigo.

In the next year Baeyer and Caro found a very simple and elegant method for preparing indol; they obtained it by passing the vapour of ethyl-aniline through a red-hot tube:

$$C_6H_5-N\Big\langle\begin{matrix}H\\ \\ CH_2-CH_3\end{matrix} = C_6H_4\Big\langle\begin{matrix}CH_2\\ \\ N\end{matrix}\Big\rangle CH + 2H_2$$

Baeyer succeeded, in 1878, in obtaining oxindol from phenylacetic acid $C_6H_5.CH_2.CO_2H$, which can be prepared synthetically by different methods, and may be easily obtained from toluol. By treating the acid with nitric acid it is converted in the orthonitro-compound, which is easily reduced to the corresponding amido-acid. But this, like several other ortho-compounds, readily loses water and yields oxindol:

$$CH_4\Big\langle\begin{matrix}CH_2.CO.OH\\ \\ NH_2\end{matrix} = C_6H_4\Big\langle\begin{matrix}CH_2\\ \\ NH\end{matrix}\Big\rangle CO + H_2O$$

This compound, as Baeyer and Knop had already found, is converted by the action of nitrous acid into nitrosoxindol. On treating this with nascent hydrogen it is transformed into amidoxindol, and this yields on oxidation isatin, the constitution of these bodies being expressed by the following formulæ:

Nitrosoxindol.	Amidoxindol.	Isatin.
$C_6H_4\Big\langle\begin{matrix}CH(NO)\\ NH\end{matrix}\Big\rangle CO$	$C_6H_4\Big\langle\begin{matrix}CH(NH_2)\\ NH\end{matrix}\Big\rangle CO$	$C_6H_4\Big\langle\begin{matrix}CO\\ NH\end{matrix}\Big\rangle CO$

I have already stated that isatin can be reduced to indigo-blue; Baeyer endeavoured now to find a more simple method for effecting this. By acting with phosphorus pentachloride on isatin he obtained a compound which he called isatin chloride, which nascent hydrogen converts into indigotin.

$$2C_8H_4ClNO + 2H_2 = C_{16}H_{10}N_2O_2 + 2HCl.$$

As far back as 1869, Kekulé predicted isatin to possess the constitution which it has been proved to have by Baeyer's researches, and two of Kekulé's pupils, Claisen and Shadwell, discovered in 1879 a very simple synthetical method for preparing it. By acting with phosphorus chloride on orthonitro-benzoic acid $C_6H_4(NO_2)CO_2H$ the chloride, $C_6H_4(NO_2)COCl$ is formed, which when heated with silver cyanide yields the nitril, $C_6H_4(NO_2)COCN$, on heating the latter with a solution of caustic potash, it is converted into orthonitro-phenylglyoxylic acid, $C_6H_4(NO_2)CO.CO_2H$ and this is converted by nascent hydrogen into the amido-compound, which, like other ortho-compounds, loses water and yields isatin.

I have now given you a sketch of the history of artificial indigo up to 1879, when I wrote: "The artificial production of indigo has so far merely a theoretical interest; whether the time will come when simplified methods will admit of its manufacture on a large scale remains to be seen. But even if not, the indigo-purpurin, which is always formed together with the blue, may become of importance as a colouring matter. This body, as Dr. Schunck has shown, is identical with his *indigorubin,* which always occurs, but in small quantity only, in indigo. Dr. Schunck has traced the formation of this beautiful purple colour in *Polygonum tinctorium,* a plant used in China and Japan for the preparation of indigo. He has cultivated it for several years, and found that the young plants do not contain a trace of it. It can be only obtained from plants having attained an advanced stage of development. It dyes under the same conditions as indigotin does; but while the latter dyes a dull dark blue, indigorubin dyes a fine purple shade. Dr. Schunck, who is an authority on these matters, is of opinion that if it could be obtained in quantity, it would be a most valuable addition to the colours now in use."*)

Since this has been written, Baeyer has succeeded in finding a method which to all probability will soon be employed for the manufacture of indigo-blue on a large scale. The starting point is from cinnamic acid, which occurs in nature, being found in Gum-benzoïn, Styrax, Balsam of Peru, and a few other aromatic bodies. These sources would be, however, far too expensive, and the quantity obtained therefrom much too small to make use of them. Now Bertagnini found, as early as 1856, that this acid may be obtained artifically by heating benzaldehyde, or oil of bitter almonds, with acetyl chloride:

$$C_6H_5.CHO + CH_3\cdot COCl = C_6H_5.C_2H_2.CO_2H + HCl.$$

Since that time several processes have been found for obtaining oil of bitter almonds from toluol and from benzoic acid. The first point to be settled was therefore to ascertain which is the cheapest and best method for preparing this compound, as well as acetyl chloride, which is produced by the action of phosphorus chloride on acetic acid.

W. H. Perkin, F.R.S., has discovered another synthesis of cinnamic acid, which probably may also be of practical value. He obtained it by boiling benzaldehyde with acetic anhydride and sodium acetate.

By the action of nitric acid on cinnamic acid we obtain orthonitro-cinnamic acid, $C_6H_4(NO_2)C_2H_2CO_2H$, which readily combines with two atoms of bromine to form dibromnitrophenylpropionic acid. This compound, by the action of alkali, is transformed into orthonitro-phenylpropiolic acid:

$$C_6H_4(NO_2)C_2H_2Br_2.CO_2H + 2NaOH =$$
$$C_6H_4(NO_2)C_2.CO_2H + 2NaBr + 2H_2O.$$

* "The Rise and Development of Organic Chemistry." Manchester, Cornish.

The latter acid yields pure indigo, when its alkaline solution is heated with a reducing agent such as grape-sugar, indigotin being deposited in the crystalline state:—

$$2C_9H_5NO_4 + 2H_2 = C_{16}H_{10}N_2O_2 + 2CO_2 + 2H_2O.$$

Besides this method Baeyer has patented some others in which also cinnamic acid is used; these processes are now worked out by two of the greatest colour-works on the Continent.

How far the artificial production of indigo will be a commercial success remains to be seen. As far as I understand, it is at present only intended to manufacture nitrophenyl-propiolic acid, which, when mixed with an alkali and grape-sugar, is printed on the cloth. By the action of steam a pure indigo-blue is produced, which would form a most valuable addition to the host of steam-colours which are now so largely in use.

In conclusion I must mention another of Baeyer's discoveries which promises to be of practical value. We can easily replace in isatin one atom of hydrogen by bromine, the nitro-group, amido-group, &c. By subjecting these substituted isatins to the action of phosphorus chloride they are converted into chlorides, and these yield by treatment with reducing agents substituted indigoes. These bodies are all coloured, and their properties are very similar to those of indigo. It appears not improbable that some of them might find application in dyeing or printing, and be prepared, not from isatin, but from substituted cinnamic acids.

When 12 years ago the artificial madder-colours were discovered, it was not believed that they could be produced in sufficient quantity, nor cheap enough to compete successfully with the natural colours. To-day the cultivation of madder has almost ceased; whether this will happen in the case of indigo is a question which I think will soon be solved.

"Some further experiments on the Cohesion of Water and Mercury," by Professor OSBORNE REYNOLDS, F.R.S.

Two years ago I exhibited before this Society a vertical tube, 60 inches long and $\frac{5}{16}$ inch in diameter, in which mercury sustained itself by its internal cohesion and adhesion to the glass to a height of 60 inches without any aid from the pressure of the atmosphere.* This tube was subsequently shown at the Royal Society and was submitted to intermittent observation at the College until about nine months ago when one day, on being erected, it either collapsed or was broken by the fall of the mercury. The fracture taking place simultaneously with the fall of the mercury, it was impossible to say which.

This tube was of common German glass, such as is used for chemical purposes, and as it proved insufficiently strong I deferred further experiments until I could obtain a tube of greater strength. This led to considerable delay, but I have now a tube 90 inches long, in which mercury suspends itself in a water vacuum resisting a tension or negative pressure of three atmospheres. Although this is probably still far short of the possible limit, a certain amount of interest attaches to the probability that the tension in this tube is the highest to which any fluid matter in the universe has been subjected.

Since my former communication, in working both with the old tube and particularly with the new and longer tube, further experience has been gained of which it is my present object to give some account.

During the year and nine months before the old tube broke no great change had been noticed in the water and mercury within the tube; the former became rather cloudy and the latter showed symptoms of a scum. These changes were but little noticed, as they did not apparently interfere with the suspension of the mercury.

* Proceedings Lit. & Phil. Soc., 1877-8, p. 155.

The most noticeable circumstance was that as time went on the difficulty of getting rid of the air and getting the tube into such a condition that its contents would sustain themselves diminished. In the first instance it had been only after a fortnight's attempts that suspension was obtained. The first successful suspension was obtained in the following manner: a little of the water was allowed to pass up by the side of the mercury when the tube was in an inclined position, the tube was then brought gently down so that the water reached the top or closed end of the tube as nearly as the air, generally a small bubble, would admit; then further inclined until the closed end was so low that the air bubble and water would float up to the open end and pass out, leaving the straight portion of the tube and part of the bend full of mercury. The tube was then left in this position for 24 hours, when on being erected the mercury sustained itself. It was then again reversed and left for some days, when on being erected not only was the mercury sustained for the 30 inches above the barometer, but it remained suspended when the pressure of the air on the lower end was reduced by the air pump to one or two inches of mercury.

No other method ever proved successful with this tube. It was always necessary to leave the tube reversed for a longer or shorter interval.

As to what went on in this interval I changed my opinion. At first I thought it must be that time was necessary to bring the mercury or water into more intimate contact with the tube, but subsequent observation convinced me that the interval was necessary to allow the water with such air as it contained to drain up between the mercury and the glass—that in this way the surface of the glass was freed from air. After arriving at this view I observed the tube carefully to see if after it had remained some days in the reversed position any trace of water was left. I could find none either while the tube was full or after the mercury had fallen; but owing to the fact that there was always water on the open end I could make no such comparison with the barometer as would show that the vacuum in the tube was absolutely free from vapour tension.

Having obtained from Messrs. Webb of Manchester tubes 12 feet long, $\frac{7}{8}$ inch external and $\frac{1}{4}$ inch internal diameter, one of these tubes was closed at one end and bent so as to leave the closed branch 7 feet 6 inches long. The bend is a curve of about 2 inches radius, and the two branches or limbs are not quite parallel; they straddle so that at 3 feet 6 inches from the bend they are 7 inches apart. At this point the shorter or open limb was again bent back through an angle of 160 degrees, so that when the main tube is vertical the mouth points downwards. The bending of so large and thick a tube was a matter of some difficulty, but was successfully accomplished by Mr. Haywood and Mr. Foster of Owens college. The tube was then firmly fastened on to a board by Mr. Foster, and the board pivoted on to a stand so that the tube can be turned round in a vertical plane.

The tube being placed so that there was a slight downward incline all the way from the open to the closed end, some water was introduced into the open end. This having passed down to the closed end and filled all the tube, mercury was introduced, which ran down, forcing out the water. As soon as the long limb and the bend were full of mercury, the tube was turned into an upright position, the mercury sinking down and forcing out the water in the shorter limb. Having reduced the water until it only occupied about 9 inches above the mercury, the tube was again brought into a somewhat horizontal position, but this time it was turned so that the mouth was downwards, the incline being from the closed to the open end. Before reaching that position the pressure of the air had caused the mercury to fill the longer limb, leaving only water in the shorter limb; as the inclination continued, the mercury and water began to change places, and the water passed up round the bend into the longer limb; when 5 or 6 inches of water had passed in, the tube was erected and turned over the other way, so that the closed end was lowest, the water and the bubble of air running up and passing out. The tube was then further inclined until nearly vertical, the closed end down, and the tube was left in this position for 24 hours.

This, it will be noticed, was the process by which, after the first trial, had proved almost invariably successful with the former tube, and the only circumstances likely to cause any difference in the new and old tube were the comparatively short time the water and mercury had been together, and in the new tube, and the greater length, 90 inches, as against 60 with the old tube. As regarded this latter difference, it would not effect a partial erection of the tube, so that if the time was not an element of importance, it was to be expected that at all events the mercury would sustain itself until the closed end had reached a position 60 inches above the bend.

On examining the tube, however, after it had been standing 24 hours, it presented a very different appearance from that usually presented by the old tube; instead of a polished column of mercury it was frosted with water between itself and the glass; it was clear that the upward draining of the water had been very imperfect, a great deal remaining adhering to the glass.

On slowly erecting the tube the mercury showed no symptom of suspension, leaving the closed end quietly as erection proceeded.

The whole process of passing the water up the tube was again repeated with the same result for three days.

The frosted appearance, however, gradually diminished and on the fourth day a partial suspension was obtained. The mercury remained up until the tube was nearly erect.

Having obtained so much, and as it appeared by the turbid state of the water that the mercury was impure, the tube was emptied, washed out several times, both with water and a solution of nitrate of mercury, and was then refilled as before with water and carefully purified mercury. At first it presented much the same frosted appearance as before, and there was no suspension.

With a view to expedite matters the board carrying the tube was taken off its pivot and laid flat on a table nearly horizontal; in this position it was so adjusted that the water and mercury both extended all along the tube. The tube was then connected by an indiarubber tube with an air pump, and the air pumped off until, and so long as, the water boiled in the tube.

The board was then turned over on its edge so that the water might come in contact with that part of the tube which had been previously below the mercury.

Having been turned back into its first position and adjusted so that the closed end and long limb were slightly lower than the rest, the pump was kept working, and the end of the board at which was the closed end of the tube was gently hit with the hand. At first this caused the mercury to chatter all along the tube, and wherever the mercury broke, a minute bubble of an air or steam showed itself; these passed slowly along to the open end; until after this had been continued for some time the chattering ceased and the last bubble had passed out.

Keeping the closed end lowest, and without breaking the connection with the pump, the board was replaced on the pivot and the tube erected. The mercury remained suspended until the tube was nearly erect, and this without any assistance from the air on the open end, so that the tension was nearly 90 inches.

The same process of tapping was then repeated, and the tube replaced and left with the closed end downwards and the air pumped off, for 24 hours. There was then no frost, but a bright column of mercury, which on erection remained suspended, the pump having been worked so as to remove the last trace of air. The tube was not left standing, but was inverted and erected for a few minutes each day for 8 days, including this morning. When the pump was again worked, and the tube sealed by clips on the indiarubber before bringing it to the Society's rooms—which somewhat difficult undertaking has been accomplished by Mr. Foster, who has assisted me throughout in these experiments. (On being erected in the Society's rooms the mercury remained suspended for about 15 minutes; it then gave way with an audible click and sank to such a level as showed that there had not been air pressure of 1-20th of an inch on the lower end.)

This experiment shows that the cohesion of water and mercury, and their adhesion to each other and glass, will withstand a tension of 3 atmospheres or 90 inches of mercury, being one atmosphere more than was shown by the former tube.

But as I have been of opinion from the first that the limit of cohesion, whatever may be that of adhesion, is a much greater quantity, my object in making and recounting these experiments has not been so much to prove a somewhat higher cohesion as to throw light upon the circumstances on which the successful suspension depends.

The fact that the frost on the glass, the imperfect draining up of the water, and the nonsuspension of the mercury all occur together, and may all be removed by time or by the complete removal of the air from the glass, seems to show that even when glass is completely wet or covered with water there may be and generally is a considerable quantity of air still adhering to the glass.

As regards the limit of the cohesive or adhesive strength of water and mercury, I conceive this to be beyond any test that can be applied by gravity. Several feet more might be attained, but the difficulties increase with the length of the tube. It has, however, occurred to me that by centrifugal force the limit may be reached in tubes a few inches long, and I am at present preparing some experiments for this purpose, of which I hope soon to be able to give some account.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

October 11th, 1880.

Alfred Brothers, F.R.A.S., in the Chair.

On some Entomostraca, &c., found in Derwentwater in September, 1879," by Mr. John Boyd.

A new Locality for Leptodora Hyalina.

"Quite a little excitement was caused in August last year by the announcement of the discovery of Leptodora Hyalina, for the first time in England, in the Olton Reservoir. The last fortnight in September I spent at Keswick, and from the description of the places in which it has previously been found here and on the Continent, I thought it very likely that it might be obtained also from Lake Derwentwater; I therefore constructed a net of fine muslin, about two feet long, gradually tapering to an aperture at the end; in this aperture I inserted the neck of a wide-mouthed bottle; this apparatus was slowly towed after a boat. The water passed through the net, leaving all the animalcules in the bottle, and to my delight almost the first haul brought up several specimens of Leptodora; afterwards I got them more plentifully, but found that in some parts of the lake the bottle brought none up. They need to be looked for very carefully, for they are so exceedingly transparent that one very easily misses seeing them. It seems to me very probable that similar lakes would all produce Leptodora if searched in this manner. The ones we obtained, although not all fully grown, were all in the mature stage, none seemed to have ova.

Besides this I got from this lake of Entomonstraca alone nine other species, viz :—

Polyphemus Pediculus, remarkable for its enormous eye and rapid movements.

Bosmina Longirostris, a comical fellow whose superior antennæ have the appearance of two elephants' trunks.

Sida Chrystallina.

Daphnella Wingii.

Alona Quadrancularis.

Chydorus Sphœricus.

Dioptomus Castor, with its enormously long antennæ; of this we only saw one male amongst the numerous specimens examined; it is easily distinguished from the female by the thickened joints in one of its antennæ.

Cyclops Quadricornis, and a beautiful variety of

Daphnia Pulex, of a greenish colour, having the carapace terminated by a long tail-like spine. This spine is a portion of the lower edge of the carapace, being strongly serrated. Of these all but the last two species were new to me, as they do not occur in any of the ponds, etc., I have examined in this district.

Amongst the Infusoria found were Melicerta ningens, having very large, light-coloured, fluffy pellets, very different to the small, dark, hard bricks composing the cell of those found about here.

Floscularia Ornata.

Uroglena Volvox.

The lovely dark green *Vorticella Chlorostigma*, and *Vaginicola Valvata*. In this last, which occured abundantly, the valve was distinctly seen, closing the sheath in an oblique direction. It is situated about one third of the length down. It was very interesting to watch the creatures push this door open as they emerged from their tubes.

These last two species I had not found before.

Rough diagrams of each of the creatures mentioned were exhibited by Mr. Boyd, and slides of Leptodora, Sida, Dioptomus, and Polyphemus.

Mr. R. Ellis Cunliffe exhibited various interesting microscopical slides.

Mr. Rogers exhibited a living specimen of an Ampullaria from Assumoroi, River Niger, West Africa. It had remained quite dormant for a considerable period, but was now in a thriving condition.

The following paper was read at the meeting held on October 19th, but only part of it printed in the last number of Procedings: —

"On some early Anticipations of Heliographic Signalling," by William E. A. Axon, M.R.S.L.

The use of the heliograph in war is likely to gain ground. *Nature* (April 29, 1880, vol. xxi., p. 617) gives an instance in which a message was flashed by this means as speedily as by the electric telegraph. The following description is given of the modus operandi: "The line of communication cannot be cut, for the simple reason that the signalling takes place over the heads of the enemy, and the stations required are but few and far between. A 10-inch mirror—and this is the diameter of the ordinary field heliograph—is capable of reflecting the sun's rays in the form of a bright spot, or flare, to a distance of fifty miles, the signal at this interval being recognisable without the aid of a glass. That is to say, two trained sappers, each provided with a mirror, can readily speak to one another, supposing the sun is shining, with an interval of fifty miles between them, provided their stations are sufficiently high and no rising ground intervene to stop the rays.

"The adjustment of the military heliograph is a very simple matter. An army leaves its base, where a heliograph station is located, and, after travelling some miles, desires to communicate with the stay-at-homes. A hill in the locality is chosen and a sapper ascends with his heliograph, which is simply a stand bearing a mirror swung like the ordinary toilet looking-glass, except that it swings horizontally. It is also pivoted so as to move vertically as well. Behind the mirror, in the very centre, a little quicksilver had been removed, so that the sapper can go behind his instrument and look through a tiny hole in it towards the station he desires to signal. Having sighted the station, adjusting the mirror, he next proceeds to set up in front of the heliograph a rod, and upon this rod is a movable stud. This stud is manipulated like the foresight of a rifle, and the sapper again standing behind his instrument, directs the adjustments of this stud until the hole in the mirror, the stud, and the distant station, are in a line. The heliograph is then ready to work; and in order to flash signals so that they may be seen at a distance, the sapper has only to take care that his mirror reflects the sunshine on the stud just in front of him."

Early in June, 1880, a writer in the *Lahore Gazette* called attention to what he regards as an early instance of heliographic signalling. He says:—

"But there is a still older instance of the use of the heliograph indicated in a ballad as old as 1511, viz., the story of the fight between the *Great Harry* and its consort under Lord Howard, on the one side, and the *Lion* and the *Union* under Sir Andrew Barton, of Scotland, on the other. Lord Howard is represented as having met at Thames mouth a merchantman which had been plundered by the Scotch admiral, and the captain offered to sail back with him and assist in the forthcoming fight if he were armed with a few pieces of ordnance. He was also to signal to the English admiral when he made out the enemy. The merchant captain says:

> 'Seven pieces of ordnance
> I pray your honor to lend to me,
> One each side of my shipp along,
> And I will lead you on the sea.
> *And a glass I'le set that may be seene*
> *Whether you sayle by day or night,*
> And to-morrow I sweare, by nine of the clock
> You shall meet Sir Andrew Barton, Knight.'

"It is clear that this glass was some sort of heliographic signal, for the ballad goes on to say:

> The merchant set my lorde *a glasse*
> *Soe well apparent in his sight,*
> And on the morrow by nine of the clock,
> He showed him Sir Andrew Barton, Knight.

"The real credit of the invention of the heliograph therefore belongs to this brave merchant captain, Henry Hunt, and even he probably only used a common means of signalling understood among all sailors four hundred years ago."

It would not follow as a matter of course that the ballad account of this battle must be regarded as a contemporary narrative. The oldest text is that in the Percy Folio, and the lines there do not refer so clearly to signalling—

> if you chance Sir Andrew for to bord,
> lett no man to his Topcastle goe;
> & I will give you a glasse, my Lord,

& then you need to fferae no Scott,
whether you sayle by day or by night;
& to-morrow by 7 of the clocke
you shall meete with Sir Andrew Barton, Knight.

The Percy Folio is probably not earlier than the black-letter copies of the ballad, but the text is altogether freer from corruptions. No existing copy of Sir Andrew Barton can claim to be older than the seventeenth century. The possibility of using the flashing of a mirror to obtain information from a distance is shown in the following extract from a book of popular science of the seventeenth century: "If there be never so dark a room with a door or window open, take a looking-glass in your hand, and hold it against the sun, at a great distance from the door or window, and moving the glass up and down, till the reflections of the sun be upon your object, and then you may perfectly behold anything in the room, or see to read a letter. Some unhappy boys used to dazzle people's eyes with a glass in this order, as they walk the streets."—This extract is from a work entitled "A Rich Cabinet with variety of Inventions." My copy of this work is destitute of title, but it was printed about 1670—80.

The "Speculum Topographicum, or the Topographicall Glasse," was "newly set forth by Arthur Hopton, gentleman," and "Printed at London by N. O. for Simon Waterson, dwelling at the signe of the Crowne in Paules Churchyard, 1611." At p. 183 we read the following: "To make a glasse whereby to discerne any small thing, as to reade a written letter a quarter or halfe a mile off. We have an imitation of such glasses as these about London commonly to bee sold, but they be so small that they stand one in small steede, but amongst the writers of perspective, I have read that if you take a glasse of the same mettall that burning glasses be, and 16 or 17 inches broad, whose center place directly against ye object you looke vpon, and let it not incline, or hang sidewise by any meanes. Behind this glasse set a faire looking glasse, the polished side beholding the said burning glasse, to ye intent to receive the beames that come through the same: which done, looke in the looking glasse, so shall you have your desire, if the burning glasse were truely placed: for you must note whatsoeuer thing you see through the burning glasse, that the further you stand from the glasse, the bigger it seemeth, untill you come to a certaine distance, and then the object seen through the glasse doth seeme lesser and lesser, therefore care must be had in placing the glasses, so may you see a Towne or Castle, or any window in the same, 6 or 7 miles, or see a man 4 or 5 miles, reade a letter in written hand a quarter of a mile from you," &c.

Hopton does not give the name of the writers from whom he derived this experiment. A partial search has not been successful in tracing it to an earlier author.

Ordinary Meeting, November 16th, 1880.

E. W. Binney, F.R.S., F.G.S., &c., President, in the Chair.

"Note on the Presence of Sulphur in Illuminating Gas," by Harry Grimshaw, F.C.S.

That crude illuminating gas from coal contains a certain amount of compounds of sulphur is of course a well known fact. That even the best quality of coal gas, when purified and made ready for consumption, contains still a certain amount of sulphur compounds is also well, but perhaps not generally, known.

An accidental, somewhat peculiar, but very practical demonstration of this fact recently came under my observation, which I thought might be of some little interest to the Society. On the interior of the glass globe surrounding a gas jet in the hall of my house I had frequently noticed the presence of drops of condensed liquid. The jet being near the outer door, and the globe consequently exposed to a rather cold current of air, I merely considered it to be drops of water formed by the burning hydrogen of the coal gas, and condensed on the cold surface of the glass. I noticed however that when the glass became heated through the turning on of a larger flame, the moisture did not, as it ought according to all reasonable expectation, evaporate. I was curious enough to take down the globe, wipe out a few of the drops on slips of paper, and rinse the rest off with water, which I preserved. Having my suspicions from the rather oily appearance of the drop, I warmed the slips of paper a little, and immediately obtained a very fine reaction for sulphuric acid, by the copious blackening and charring of the paper in those places where the liquid had touched it. I then applied the usual chloride of barium test, and obtained a plentiful precipitate of sulphate of barium from the washings of the globe; thus showing, of course, that the oily drops were literally nothing but tolerably strong oil of vitriol.

The genesis, so to speak, of these drops of sulphuric acid is of course easily explained and pretty well understood. The sulphur of course originally exists in the coal used for gas making, mostly combined with iron as sulphide. In the crude coal gas it exists as sulphuretted hydrogen (H_2S), bisulphide of carbon (CS_2), and to a small extent as sulphur dioxide (SO_2). The greater portion of these compounds of sulphur are absorbed by the ammonia liquor which condenses from the gas itself in the scrubbers, and by the lime and oxide of iron in the purifiers, through which the gas passes on its way to the gasholder; but nevertheless a sufficient quantity remains in the gas to produce the effect above described and to also produce a bright but very objectionable green deposit of sulphate of copper on the brass of the gaspipe above the jet I have alluded to.

The presence of the corrosive substances, sulphur dioxide and sulphuric acid in the products of combustion of coal gas, has always been known and always acknowledged, and yet but little notice of their effects has been taken. It has been said, "The quantity is so small and is disseminated through such a bulk of other gaseous bodies." It is as well to see what this means. If the amount of sulphur in coal gas is reduced to 10 grains per 100 cubic feet, it is considered a very pure gas indeed. Manchester gas is supposed to attain to this degree of purity, and is, I believe as a rule, a better gas in this respect than that of many other towns, For my own part I should feel inclined to think that only a small portion of the gas made in this country uniformly reaches this standard. However, say that the gas which I burn in my house contains no more than 10 grains of sulphur per 100 cubic feet. This means 100 grains, or about a quarter of an ounce (about) per 1,000 cubic feet. I find that I burn on an average, through 5 or 6 jets per evening 89,00 cubic feet per quarter. This contains 890 grains of sulphur, which is equal to 2,670 grains of sulphuric acid (H_2SO_4); so that I turn into the atmosphere of my house, mostly into one room, nearly 6 ounces of sulphuric acid in three months. This is 24 ounces, or $1\frac{1}{2}$ pounds per annum. Now if I had been burning the Leeds gas, of the quality which has recently been subjected to a good deal of criticism, and which is stated to contain 40 grains per 100 cubic feet, then I should be subjecting the contents of my house to the action of $1\frac{1}{2}$lbs. of vitriol per quarter, or 6lbs. per annum In many cases, certainly in those cases where the contents of the room are most liable to damage, the above amount of gas, namely that from 5 or 6 lights, is given off into the atmosphere of one room.

Almost all the objects in the upper parts of a room are susceptible to damage by the vapour of sulphuric acid. I do not take into consideration the presence of sulphur dioxide, for it is almost impossible that this body could escape conversion into sulphuric acid in a very short space of time, in the presence of oxygen, the vapour of water and heat. Ceilings, cornices, wallpapers, pictures, with their cords or chains, and frames, books, and so on, are all objects which are susceptible to the corrosive action of the vapour of sulphuric acid, and there cannot be much doubt that in a longer or shorter time they will all suffer from the presence of the sulphur in gas where the latter is burned in any quantity. The great danger in the action of sulphuric acid, in these cases is that it is a cumulative one. Its action will be accumulative in a longer or shorter time under the following conditions respectively, burning the same amount of gas in each case. In a longer time if the ventilation is *very good*, and the walls of the apartment perfectly free from any *dampness*. In a shorter time when these two conditions are unfavourable, especially when the walls or portions of them are not perfectly dry, the presence of moisture naturally favouring the formation of sulphuric acid, and also absorbing it when formed and assisting its action. In such cases I have known a most rapid action upon wallpapers of certain kinds and on organic materials where in contact with metals, notably brass, both the metal and the organic fibre being rapidly corroded.

Many of the objects in the upper portions of rooms to which I have alluded are replaceable, at some little expense of course, such as the colouring of ceilings and wallpapers, and we may make up our minds to putting up with their deterioration for the sake of the excellent light and convenience of gas-lighting; but to expose such objects as valuable pictures and books to the extensive action of the products of combustion of coal gas as we at present consume, is most injudicious, and is, there can be little doubt, the cause of a great deal of irreparable injury in many cases. My own opinion is, that now that mineral and other oils for illuminating purposes are so cheap, and lamps for their consumption are so admirably constructed and elegant in design, there is not the slightest reason why valuable collections of pictures and books should be exposed to the sulphurous emanations of coal gas.

Since writing the above I find by an abstract in the Journal of the Chemical Society (1880, vol. ii., p. 836) that a Mr. W. R. Nichols confirms the generally accepted view that the deterioration of library bindings is mainly due to the action of the sulphuric acid from coal gas, and he finds that morocco is not so much affected as russia leather and calf skin, and that ordinary sheep skin is attacked by this body.

ADDENDA.—For methods of estimating the sulphuric acid formed during the combustion of coal gas, and proof that suphuric acid is formed, see Young and others. Analyst, Vol I., p. 143.; Vol. II., pp. 66, 67, 118, 133, 135, 139; and Vol. III., p. 201. For the effect of gas on the books of the Libraries of the Athenæum, London, Royal College of Surgeons, Portico Library, Manchester, and Literary Society, Newcastle-on-Tyne, see Dr. Letheby's earlier reports to the London Corporation.

Ordinary Meeting, December 14th, 1880.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

"Boulder Stones as Grave Stones."

The President said that in the numerous excavations made in the drift deposits large boulder stones are often met with and cause a good deal of trouble to the workmen. They are glad to get quit of them somehow or other. Blasting them with gunpowder or dynamite or burying them near to the place where they have been found have been generally employed. Latterly it has become the fashion to remove them to public parks in order to preserve them; and fine specimens may be seen in those places at Manchester, Salford, Oldham, and Macclesfield, where they are not only preserved, but exposed to public attention. He (the President), when visiting Ashton-under-Lyne the other day, observed another use to which boulder stones had been applied. There in the churchyard on the Manchester Road a greenstone boulder, instead of being buried as was formerly the custom, is now used as a tombstone over the grave of a son of an alderman of that borough. This is the first instance where he had seen a boulder stone used for such a purpose, and it is one where they may not only be preserved, but exhibited to the public. Over the grave of the late Mr. Locke the Railway Engineer, in Kensal Green Cemetery, is a block of red granite, but although plain, he thinks it is not a boulder like the one at Ashton-under-Lyne.

"The Land Subsidence at Northwich," by Thomas Ward, Esq.

Having been an eye witness of the great subsidence of land at Northwich on December 6th, I will endeavour to explain how it arose. The district, of which Northwich is the centre, has two beds of rock salt underneath it. The first one, about 40 yards from the surface, is on the average 25 yards thick. Below this there is a bed of much indurated clay about 10 yards thick, and below this again the bed of lower rock salt some 35 yards thick. From 1670 to 1780 all the rock salt mined was obtained from the "Top Rock," as it is locally called, and the miners left too few supporting pillars, and these not large enough, besides working the salt out so as to leave only a comparatively thin crust of salt as a roof. The great majority of the mines in the Top Rock salt have fallen in wholly or partially. Since 1780 the rock salt has been "got" from the lower bed, and the pillars, especially of late years, have been left much larger, the roof at the same time being much thicker. Only from 5 to 6 yards of salt near the bottom of the bed has been worked. As a rule the mines in the bottom rock salt have stood firm, and where the owners have worked to their boundaries they have allowed the brine to run into the worked-out mines, thus converting them into reservoirs. The quantity of rock salt mined is small compared with the white salt manufactured. The white salt is made from a natural brine which is found on the surface of the "Top Rock." It is found much cheaper to let the water do the mining and then pump up the salt in solution and drive off the water. The fresh water, as soon as it reaches the rock salt, eats it away till it gets fully saturated. This water running over the roofs of the old "Top Rock" mines has in numbers of cases eaten the whole of the salt away and opened a communication into the mine below. The overlying clays and earths, being deprived of their support, fall into the cavity thus opened, and a hole is made from the surface. On December 6th this was what occurred, and a hole or rift opened right across the course of the Wincham Brook, the water immediately rushing below. As the mines in both "Top" and "Bottom" rock were nearly exhausted of brine, the cavities to be filled were enormous. Directly beneath where the fall occurred, and bordering on an old abandoned Bottom Mine, was a rock salt mine being worked. The barrier between the two having been on two occasions penetrated, it now gave way, and opened a communication with 15 acres of mine having a worked-out depth of about 18 feet. Into this mine, down a funnel of 100 yards in length from the surface, the water rushed with great velocity, causing the lower portion of the brook to retrace its course and drain off a large body of water from the River Weaver and an adjoining lake called the Top of the Brook. This immense body of water, rushing into the underground cavities, drove out the air contained therein, and so violent was the compression of the air that it forced its way through every portion of the contiguous district that was in the least rifted or weak, showing itself in violent ebullitions in all the neighbouring pits and where the earth was fractured, causing a number of miniature mud geysers of 10 to 12 feet in height. Much property was seriously damaged, and a considerable piece of land covered with water. Five sets of salt works are stopped owing to the destruction of a road and the pipes conveying the brine from the pumping district to the works. The greatest sufferers by this subsidence had little to do in causing it, and this is one of the great anomalies of the system of obtaining salt. The property of numbers of persons in no way connected with the salt trade is seriously injured, and under the existing law no compensation can be obtained.

This great subsidence is interesting from a geological point of view, as showing the action of natural forces, and illustrating how change of surface may occur. A counterpart of the Old Salt Lake of Triassic times is in process of formation.

"Some endeavours to ascertain the nature of the insoluble form of Soda existing in the residue left on Causticizing Sodium Carbonate Solutions with Lime" (Part II.), by WATSON SMITH, F.C.S., Assistant Lecturer on Chemistry in the Owens College, and Mr. W. T. LIDDLE. Communicated by Professor C. SCHORLEMMER, F.R.S.

At the close of our last paper we mentioned that it was our intention to try certain further experiments with the crystalline precipitate obtained by mixing solutions of sodium carbonate and lime water and warming, and also with ordinary "*lime-mud*" from the causticizing pan of an alkali-works, after the usual washing and draining. The experiments we proposed to try were:

(1) The effect of ignition upon the crystalline precipitate prepared as above, and upon the "*lime-mud*" of the soda-works.

(2) The effect of long continued boiling with water.

(3) The effect of boiling with some saline solution, as for example with sodium sulphide.

Two fresh samples of the crystalline precipitate were now prepared, each in rather a different manner from the other. In the first case lime water was used in slight excess, and the sodium carbonate solution was dilute; in the second a strong solution of sodium carbonate was employed, the sodium carbonate being in excess. The precipitates obtained in both cases appeared under the microscope similarly crystalline; we will call them A and B respectively. On analysis the following results were obtained, after the precipitates had been washed with hot water till quite free from all soluble alkali:

	A.	B.
Calcium carbonate	98·07%	98·11
Sodium carbonate	1·93%	1·88
	100·00	99·99

(1) A weighed quantity of dried precipitate, previously well washed from all soluble alkalinity, was now ignited

strongly for about an hour, subsequently treated with dilute spirits of wine (water and alcohol, 5:2) filtered, washed well, any little lime in the filtrate precipitated, again filtered, washed, and the filtrate finally evaporated to dryness and weighed. Thus it was found that every trace of soda was extracted from the substance, both by examining the perfectly white sodium carbonate obtained, qualitatively, and also the residue of calcium carbonate with the spectroscope. The weight of Na_2CO_3 extracted was found to be 2·00%, closely agreeing with the amounts determined. (See above analyses A and B.)

(2) A weighed quantity of the crystalline precipitate was now subjected to a six-hours' continuous boiling with water, adding water from time to time to replace that evaporated. By this means 1·7% Na_2CO_3 was extracted, leaving about 0·2% Na_2CO_3 in the residue, which the six-hours' boiling therefore failed to remove. The residue on spectroscopic examination showed that soda still remained behind. Doubtless another hour's boiling would entirely remove it.

(3) The effect of boiling for six hours with a solution of sodium sulphide, obtained by lixiviating the mass resulting after fusing a mixture of ordinary salt-cake and charcoal, showed us that by this means much less soda is extracted than when pure water is used. The six-hours' boiling extracted only 0·5% Na_2CO_3, thus leaving about 1·4% insoluble in the residue. The crystalline precipitates we obtained as described were anhydrous as the analyses show.

With regard to the *lime-mud*, the soda insoluble in water, and which long washing with hot water could not remove, was found in another sample of the mud to be 2·10% Na_2CO_3, the amount of soluble alkali = 2·62%, giving a total content of soda as

2·10%	Na_2CO_3	insoluble
2·62%	„	soluble
4·72%	„	total.

The water in the lime-mud was estimated by heating to 110° in a current of hydrogen till a constant weight was obtained. Thus 34·6% of water was found, and calculating now on *dry residue*, we get as

Na_2CO_3	insoluble,	3·21%
„	soluble,	4·00%
„	total	7·21

(1) After first washing a weighed quantity of the lime-mud, passing CO_2 to convert any lime into carbonate, and washing again to remove soluble alkali, the residue was ignited for an hour strongly, and then after a thorough washing with dilute alcohol, precipitation of any dissolved lime in filtrate, determination of soda obtained, and spectroscopic examination of residue, we found all soda was thus removed. This result agrees with that obtained by ignition of the precipitates we prepared. Kynaston found the same many years ago, in some examinations of lime-sludge, and hence we can quite confirm his results.

(2) The experiment was now tried of boiling a weighed quantity of the mud (having first passed CO_2), for six hours continuously with water, from time to time replacing what was lost by evaporation. The whole was now filtered and washed thoroughly, the filtrate being carefully evaporated to dryness. The residue gave a slight soda reaction in the flame, and was dissolved in hydrochloric acid, lime and other bodies precipitated (a little iron and alumina with ammonia, and the calcium as oxalate), and then this filtrate was also evaporated to dryness. By this means it was found that practically all the soda was extracted by the prolonged boiling, the amount left behind being inappreciable.

It may now be interesting to mention that Fritzsche in 1864 (Journ. für Prakt. Chem. 93, 339) succeeded in obtaining crystals artificially of the body till then only known as a mineral under the name of "*Gay-Lussite.*" These crystals he obtained by the action of a boiling solution of sodium carbonate upon a smaller quantity of a solution of calcium chloride of 1·13 spec. gr., and letting the whole stand for some days. The analyses of these crystals showed them to consist, as Gay-Lussite does, of $CaCO_3$, $Na_2CO_3 + 5H_2O$. On heating with water the body is decomposed, sodium carbonate being dissolved and calcium carbonate being left behind. It was also found that the salt, when dehydrated, is more easily and quickly decomposed by water than before dehydration, and it would appear in fact as if the calcium carbonate and sodium carbonate were simply held together by the water of crystallisation.

When Fritzsche came to analyse the crystalline body he obtained, he attempted it by washing out the sodium carbonate, igniting the residue of calcium carbonate, and weighing the calcium oxide remaining after the ignition. On testing the residue by solution in very little hydrochloric acid, a very small evolution of carbon dioxide was observed, and this led to further examination, resulting in the discovery of a small quantity of sodium carbonate which had remained insoluble with the calcium carbonate. Fritzsche promised to experiment further in this new direction, but it does not appear that he has. Nevertheless, the results he obtained show that in two experiments the quantities of sodium carbonate retained as insoluble in the calcium carbonate residue, after careful washing, were, (1st) 1·8 per cent, (2nd) 2·4 per cent, thus closely agreeing with the amounts we found in our crystalline precipitates, the analyses of which are given above.

Of course we are aware that several speculations might be advanced to account for the occurrence of the soda in the calcium carbonate in the insoluble form, but it seems to us most in accordance with the results we have obtained, with others, to view it as combined with an equivalent proportion of calcium carbonate, an insoluble compound being formed.

The practical bearing of our results would seem to be upon (1) the "causticizing process," and (2) on the "black ash" process of the soda manufacturer. In the first case, as already mentioned, the residual soda is kept in circulation in the process, and so is not lost, the lime-mud being drained, and used again in the black ash mixture. In some works, however, where black ash is not made, *e.g.*, soap works, causticizing from soda ash, &c., an average loss of about 7¼ per cent Na_2CO_3 of the dry residue or 4·7 per cent of the washed and well-drained mud, is sustained. In the second case, it is evident that an adequate improvement, by which a minimum amount of calcium carbonate is used in the black ash mixtures, must effect an improved yield of soda or lixiviation, a smaller retention as insoluble compound in the soda-waste occurring. Wright's results and remarks on this head, are valuable. (See his paper, already cited—Part I).

Ordinary Meeting, December 28th, 1880.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

"The Literary History of Parnell's Hermit," by William E. A. Axon, M.R.S.L., &c.

In this paper the author traced the story of the angel and the hermit which forms the subject of Parnell's "Hermit." Voltaire, who used the same apologue, was thought to have copied it from Parnell, but it has been used by many others. James Howell, Sir Philip Herbert, Dr. Henry More, and Thomas White employed it in the seventeenth century, and Luther Bradwardine and Herolt still earlier. It occurs in Gesta Romanorum and other similar collections of the fourteenth century, and in various recensions of the "Vitæ Patrum." It is also in the Koran, and had probably been borrowed by Mahomet from a Jewish source, as a very interesting form of it is in the Talmud.

The relations of those different versions to each other was then discussed at some length in their connection with the history of fiction.

General Meeting, January 11th, 1881.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

Mr. Daniel Adamson, F.G.S., of the Towers, Didsbury, was elected an Ordinary Member of the Society.

Ordinary Meeting, January 25th, 1881.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

R. D. Darbishire, F.G.S., read a paper "On the Question of the desirability of the Society's Library being handed over to the Free Reference Library of the Corporation."

Only two of the 26 members present were in favour of Mr. Darbishire's proposal, and a letter from Dr. Schunck was read also in favour; but letters from Dr. Clay, Dr. Roscoe, Mr. W. H. Johnson, Mr. Cottam, and Mr. Baxendell were read against the proposal.

Ordinary Meeting, February 8th, 1881.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

Mr. Lund, F.R.C.S., exhibited a new form of mercurial thermometer by Mr. Fraser, of Edinburgh.

Mr. S. C. Trapp and Mr. W. H. Johnson were appointed Auditors of the Treasurer's accounts.

Ordinary Meeting, February 22nd, 1881.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

The President reminded the members present that yesterday was the 100th anniversary of the first meeting of the Society.

Dr. Balfour Stewart, F.R.S., communicated the following letter from Mr. Herman Hager:—

1, Derby Road, Fallowfield,
February 8th, 1881.

Dear Dr. Stewart,

I have found in Schultz Das Höfische Leben the following notes with regard to severe winters and famines:

1100. Very severe winter, famine, great mortality.
1111. Very severe winter, great famine and mortality.
1115. Very severe winter.

1124. Great famine in England, severe winter, the Rhine frozen over and used as a high-road.

1125. Bad harvest, in consequence famine in France from November 1st to the next harvest, winter very severe.

1133. Rather bad harvest.

1134. Likewise bad harvest owing to protracted drought.

1137. Unheard of drought, famine begins, which lasts 11 years.

1142. Hard and long winter, great floods.

1144. Very bad winter, famine, harvest began August 30th instead of July 25th.

1145. Plague and famine.

1146. Famine.

1149. Very hard winter, sea frozen 3 miles (German) out from the coast, dearth, great famine in Austria.

1150. Very hard winter.

1151. Great famine.

1153. Saevientis hiemis insolita asperitas.

1155. Bad harvest, famine.

1159. Severe winter.

1161. Everywhere great famine.

1162. Dearth.

1167. Very severe winter.

1168. Famine.

1171. Great drought, beginning of dearth.

1172. Dearth.

1173. Unusually severe winter, much mortality.

1174. Famine.

1175. Famine in England.

1176. Famine in France.

1177. Famine and dearth.

1179. Hard winter.

1181. Great drought, dearth.

1821. Famine in Italy.

1183. Very hard winter.

1188. Bad harvest, famine, unheard of drought.

1191. Famine in Italy, much sickness in Austria.

1194. Famine.
1195. Famine in Austria, in France begins a famine lasting 4 years.
1196. Great famine in Germany and France, very bad harvest.
1197. Famine continued.
1202. Dearth in Italy.
1204. Famine, severe winter.
1205. Severe winter.
1206. Great famine.
1212. Famine in Upper Italy.
1216. Very severe winter in Upper Italy.
1224. Long winter, famine in Upper Italy.
1227. Great famine.
1231. Dearth.
1233. Severe winter.
1234. Severe winter in Italy.
1235. Great famine in France.
1240. Dearth.
1247. Famine.
1252. Very cold winter, rivers frozen 6 feet down, great famine in Austria.
1253. Severe cold.
1258. Dearth all over Italy.
1261. Great dearth in Germany.
1264. Great famine in Suabia.
1270. Famine in Germany.
1271. Great dearth in Parma.
1277. Dearth in Italy, famine in Poland.
1281. Famine in Bohemia and Silesia.
1282. Famine in Poland.
1315. Terrible famine in Livonia and Esthonia.

There are many more particulars in Schultz about comets, earthquakes, etc., but if I understood you rightly, you did not want those for your present purpose.

Yours very truly,
HERMAN HAGER.

"Ozone and the Rate of Mortality at Southport during the Nine Years, 1872—1880," by JOSEPH BAXENDELL, F.R.A.S.

It is commonly supposed that the salubrity of a town or district is indicated by the greater or less amount of free ozone usually present in the atmosphere, and the results of occasional comparisons of the observed amounts of ozone with the rates of mortality have generally tended to support this view; but in order to ascertain clearly the nature and extent of the connection between the amount of ozone and the rate of mortality, it is evidently necessary that before comparison with the rate of mortality is made, the registered results of ozone observations should be corrected for the effects of the various meteorological causes which are known to influence the observed amounts of free atmospheric ozone. Among these causes, the velocity of the wind is by far the most important. Other things being the same, the greater the velocity of the wind and the greater will be the registered amount of ozone. I therefore calculated the mean daily velocity of the wind for the nine years 1872—1880, from the observations taken with the Robinson anemometer mounted by Mr. Dancer at the Southport Meteorological Observatory, and as I had found that the variations in the recorded amounts of ozone are approximately proportional to the variations in the mean daily velocity of the wind, I calculated the corrections necessary to be applied to the observed amounts of ozone to reduce them to what they would have been had the mean velocity of the wind been the same in every year. The data used in the calculations, were the mean velocity of the wind for the nine years, 266·9 miles; the mean amount of ozone for the same period, 5·07, and the mean velocity of the wind, and mean amount of ozone for each year.

Year.	Mean Velocity of the Wind in Miles.	Mean Observed Amount of Ozone.	Correction for Velocity of the Wind.	Corrected Amount of Ozone.
1872	311·4	5·60	—0·80	4·80
1873	296·8	5·40	—0·54	4·85
1874	294·0	4·91	—0·45	4·45
1875	269·2	4·21	—0·04	4·17
1876	271·6	4·51	—0·08	4·43
1877	286·3	6·01	—0·41	5·60
1878	242·8	5·30	+0·53	5·82
1879	213·8	4·96	+1·23	6·19
1880	216·1	4·72	+1·11	5·83
Means	266·9	5·07		5·13

It appears, therefore, from the numbers in the last column of the above table, that when allowance is made for the velocity of the wind, the mean amount of free ozone in a given volume of the air in Southport—say, for instance, the average quantity that enters into the lungs of a healthy person during a day—was least in 1875, and greatest in 1879; and that in each of the five years 1872—1876 the mean amount was below the average for the nine years, while in the four years 1877—1880, during which considerable improvements in the sanitary condition of the borough have been made, the mean amount has been much above the average.

Comparing now the corrected annual amounts of ozone with the death rates of the borough, we have the following results:

Year.	Corrected Amount of Ozone.	Gross Death Rate.	Local Death Rate.	Zymotic Death Rate.
1872	4·80	22·82	18·06	2·06
1873	4·85	22·03	18·91	3·74
1874	4·45	22·14	18·42	3·11
1875	4·17	22·37	19·28	2·64
1876	4·43	21·06	17·63	2·82
1877	5·60	19·75	16·42	1·69
1878	5·82	19·71	16·35	2·13
1879	6·19	18·09	15·48	0·73
1880	5·83	20·73	18·35	1·43
Means	5·13	20·97	17·65	2·26

An examination of the numbers in this table shows that in the five years 1872—1876, when the mean amount of ozone was always below the average for the nine years, the gross death rate was always above the average, while in the four years 1877—1880, when the mean amount of ozone was always above the average, the gross death rate was always below the average. In four of the five years of lowest amount of ozone, the local death rate was above the average, and in the fifth year it was almost exactly the average; while in three of the four years of highest amount of ozone, the local death rate was below the average, but in the fourth it was above. It must, however, be remarked, with reference to this year, 1880, that the death rate is based upon an uncertain estimate of the population, and therefore may admit of material correction when correct returns of the population shall have been obtained. In four of the five years of low amounts of ozone, the zymotic death rate was above the average, and in the fifth slightly below; and in the four years of high amounts of ozone the rate was always below the average.

During the five years of low amounts of ozone, the gross death rate was 12·8 per cent greater than in the four years of high amounts of ozone; the local death rate 10·9 per cent and the zymotic death rate 92·6 per cent greater.

I have only to add that a comparison of the general results of the observations of temperature, humidity of the air, direction of the wind, and rainfall, with the ozone results, shows that although these elements have sometimes an influence upon the amount of ozone during short periods, yet that, taking a period of a year, the opposite effects during the short periods so far neutralize each other that the mean amount of ozone for the year is not affected by them to any very sensible extent, so that we are fully entitled to conclude that the corrected amounts of ozone given above fairly represent the actual degree of purity of the air of Southport during the last nine years, and that variations in the actual amount of free ozone exercise a very sensible influence upon the state of the public health.

The PRESIDENT exhibited to the meeting an iron key, a leaden seal of the Duchy of Lancaster, an ancient spoon, and a curious piece of lead with an old English alphabet on it, all found in digging the foundations for some new buildings on a piece of land lying between Hanging Bridge and Cateaton Street in Manchester.

The land from Church Gates in Cateaton Street to the river Irwell on the west slopes gently, and the underlying rock is the Trias sandstone so commonly seen on the banks of the Irwell, covered by about 27 feet of valley sand and gravel. It has been much changed in appearance since the waters left it and retired to their present bed, as from the excavations made in his land there was the course of a small brook spanned by a bridge of two arches, now covered by broken stones and rubbish, and connecting Cateaton Street, along Hanging Bridge, with the site of the Cathedral.

His architect, Mr. Henry Worthington, of this city, collected the specimens now on the table, and to him he was also indebted for the sketch of the two arches, under the most northern of which the small stream of about 18 inches wide and 7 inches deep flows. It was in and near the bed of this stream that the objects were found, having been probably thrown or dropped in from the Hanging Bridge.

The seal of the Duchy appears to be of about the commencement of the fifteenth century, is a casting in lead of about 2 inches in diameter, and has a hole in it as if it had been attached to some body by a string.

The old spoons, which are of lead, and key of iron, are of ancient date, but their exact age it is difficult to say.

The small piece of lead, $\frac{1}{8}$ of an inch thick, about $1\frac{1}{2}$ inches long, by $1\frac{1}{4}$ inches broad, and having a slight handle of about half an inch, has in relief on one side an ancient alphabet, and on the other a cross. Now, Chambers, in their Book of Days, at page 47, in giving a description of Horn Books, say that "they are now very rare, even the most modern ones, and that the alphabet on them was invariably prefaced with a cross, whence it came to be called the Christ Cross Row, or, by corruption, Criss Cross Row, a term which was often used instead of Horn Book. In earlier times it is thought that a cast leaden plate, containing the alphabet in raised letters, was used for the instruction of the youth of England, as Sir George Musgrave, of Eden Hall, possesses two carved stones, which appear to have been moulds for such a production." In the specimen found at Hanging Bridge, the letters are not prefaced with a cross, but the cross appears on the back. However, the supposition that some of the earlier of these Criss Cross Rows were in ancient times cast in lead has received a remarkable confirmation by the finding of his specimen, and he hoped some time to be able to compare his cast with the mould in the late Sir George Musgrave's possession. The characters of the letters appear to be about the beginning of the fifteenth century.

"On the Addition and Multiplication of Logical Relatives," by JOSEPH JOHN MURPHY, F.G.S.; communicated by the Rev. ROBERT HARLEY, F.R.S.

In this paper the Logic of Relatives means any logical system wherein each relation is expressed by a special literal term. The common logic is co-extensive with so much of the Logic of Relatives as deals with the relations of inclusion and exclusion. These relations are expressed in the present system by L and N respectively, so that "A is B," or "A is included in B," is expressed by

$$\mathrm{A} = L\mathrm{B} \text{ or } \mathrm{B} = L^{-1}\mathrm{A},$$

and "A is not B," or "A and B exclude each other," is expressed by

$$\mathrm{A} = N\mathrm{B} \text{ or } \mathrm{B} = N\mathrm{A}.$$

The problem of the multiplication of relatives is :—Given the relations of any two terms to a third term, to find the resultant relation of the first two to each other. This is identical with the problem of syllogism; thus, if

$$\mathrm{A} = L\mathrm{B} \text{ and } \mathrm{B} = M\mathrm{C},$$

where L and M are any relative terms whatever, it follows that

$$\mathrm{A} = (L \times M)\mathrm{C}.$$

Prof. Pierce (*Logic of Relatives,* Memoirs of the American Academy, vol ix.) speaks of the multiplication of relatives in this sense. But the corresponding problem of their addition, so far as I am aware, is now stated for the first time.

The problem of the addition of relatives is :—Given any two relations subsisting between the same terms, to find the esultant relation.

Let us, for the sake of simplification, adopt De Morgan's method of working in an arbitrarily limited universe. The simplest possible case is that of a universe of only two individuals, exactly alike except in name, and each having an indefinite number of names. Let the relation between the names of the same individual be symbolised by 1, and the relation between the names of the different individuals by -1. Four syllogisms arise by the multiplication of these relations, and may be expressed by the following "canonical equations," all of which are true also in common algebra.

$$1 \times 1 = 1$$
$$1 \times (-1) = -1$$
$$(-1) \times 1 = -1$$
$$(-1) \times (-1) = 1$$

Which are thus expressed in language :

Identical if identical is identical.
Identical if opposite is opposite.
Opposite if identical is opposite.
Opposite if opposite is identical.

By the addition of the same relatives we get the following canonical equation,

$$1 + (-1) = 0,$$

which is also true in common algebra, and is the expression for the universe under consideration, of the truth that contradictory relations cannot coexist.

If, as before, we express the relation of inclusion by L, and the converse relation by L^{-1}, then

$$L + L^{-1} = 1.$$

That is to say, if A is included in B and also includes B, then A is identical or coextensive with B.

If, as before, L means inclusion and N exclusion, then

$$L + N = 0,$$

that is to say, these relations are contradictory.

Relatives are either invertible or uninvertible, and either transitive or intransitive. Using L as the symbol of relation generally, the symbol of invertibleness is

$$L^{-1} = L,$$

and the symbol of transitiveness is

$$L^2 = L.$$

There are thus four classes of relations.

1. Transitive and invertible. To this class belong the relations of identity, and similarity in any one respect. The only numerical coefficient that combines these properties is unity.

2. Transitive and uninvertible. To this class belongs, among others, the relation of inclusion. The only numerical coefficients that combine these properties are zero and infinity.

3. Intransitive and invertible. To this class belongs, among others, the relation of exclusion. The only numerical coefficient that combines these properties is negative unity.

4. Intransitive and uninvertible. To this class belong an infinite variety of relations:—among others, partial inclusion (some A is B). These properties are combined in all numerical coefficients except unity, negative unity, zero, and infinity.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

2nd November, 1880.

ALFRED BROTHERS, F.R.A.S., President of the Section, in the Chair.

Mr. E. WARD exhibited some microscopic slides containing vegetable sections double stained.

Mr. THOMAS ROGERS exhibited specimens of Chiton scabridus (Jeffreys), from Jersey, collected by Duprey. It appears to be rare. Dr. Jeffreys thought at first that it might have been a variety of Ch. cancellatus, but the arrangement of the sculpture, and its somewhat different form, lead him to believe it quite distinct. Mr. Duprey finds it under stones, along with C. cancellatus, Rizzoa lactea, R striatula, and Adeorbis sub-carinatus.

Mr. THOMAS ROGERS also exhibited a prepared section of the palate of an African species of Ampullaria, which had been shown in a living state at the last meeting of the Section.

Prof. W. C. WILLIAMSON, F.R.S., exhibited a large mass of one of the Nidulariæ from Mr. H. D. Pochin's estate in North Wales. Also some slides of Ascobolus, in various stages.

Prof. WILLIAMSON explained the bisexual reproduction of one of the the fresh water Vaucheriæ.

Dr. JOHN TATHAM, through Mr. Bailey, submitted a form of erecting microscope designed by Mr. Stephenson, which worked very well when used for dissecting.

Mr. T. H. BIRLEY read a paper explantory of the process adopted by Herr Herpell, of St. Goar, in preparing specimens of Hymenomycetous Fungi.

2nd December, 1880.

R. D. Darbishire, F.G.S., Vice-President of the Section, in the Chair.

Mr. Robert E. Cunliffe submitted a copy of the General Introduction to the reports of the "Challenger" expedition, and reported the progress made in the publication of some of the reports.

Mr. Samuel Moore exhibited a parasitical Alga which he had found at Bridlington, growing upon Griffithsia equisetifolia.

Mr. E. Ward presented to the Society's cabinet a slide containing valves of Aulacodiscus Africanus, which he had selected from a collection placed in his hands by the Section at the close of last session.

Mr. John Plant, F.G.S., gave an account of his dredging experiences in Cymmeran bay, from Rhoscolyn to Aberffraw, on S.W. coast of Anglesea, in the years 1874 to 1880, and submitted a list of 191 species of marine molluscs occurring in that locality during the period named.

January 17th, 1881.

Alfred Brothers, F.R.A.S., President of the Section, in the Chair.

Mr. Plant, F.G.S., exhibited some remarkably large and fine shells of the pearl oyster (Meleagrina margaritifera), from Somerset, Australia. Also a selection of N. American Unionidæ.

Mr. Hastings C. Dent exhibited specimens of Anastatica hierochuntica (L.), "The Rose of Jericho," and read a paper thereupon.

Mr. R. D. Darbishire, F.G.S., exhibited specimens of the rare fresh-water bivalve Mülleria lobata, from Bogota, S. America, and explained the unique process of its growth.

Mr. Lionel E. Adams gave an account of a luminous centipede observed by him in a garden at Maidenhead, Bucks, probably a species of *Geophilus*.

Mr. Charles Bailey, F.L.S., presented to the Section a copy of the new London catalogue of Musci and Hepaticæ known to occur in the British Islands.

PHYSICAL AND MATHEMATICAL SECTION.

November 9th, 1880.

E. W. Binney, F.R.S., F.G.S., President of the Section, in the Chair.

"On Gravitation," by the Rev. Thomas Mackereth, F.R.A.S., F.M.S.

All life, motion, energy, and force are to us only such as their vehicles present them, or as they make us conscious of their existence. In what I am about to discuss I wish to include whatever originates force or effort under the name of *conatus*. And of *conatus* in any way, I venture to assert that we can know nothing excepting as it may be presented by and through either its assumed or sensible vehicle. Therefore it is impossible to think of a *conatus* without thinking of or assuming a vehicle or subject. Hence, to know a *conatus* we must know its subject. Again, *conatus* acts from within in its subject to sustain it, and by this effort the subject can act upon other subjects from without, and other subjects can react from without upon it; and thus the *conatus* within a subject can be brought into contact with other subjects from without to produce an effect. Without this action and reaction existence is impossible.

Each atom in the universe according to its ability attracts to itself every other atom of the universe. This *conatus* must be within each atom, but it is the subject or vehicle of this *conatus* which produces the effect of presence by the power of attraction. Thus the subject or substance of the atom could not subsist without the internal *conatus*, and the *conatus* could not produce the effect of presence without the substance of the atom. As regards size or bulk, an atom is the smallest and simplest subject or vehicle of *conatus*; but I think it possible to show that there are simple subjects of enormous extent. Before proceeding to that part of the discussion, and for the sake of more clearly illustrating the meaning of what I have to say, I would observe that all the visible subjects of nature are more or less compounds of *conatus*, that is to say, many kinds or intensities of force and their subjects exist in one subject, yet in that subject there is one *conatus* that controls the whole, and makes out of many a unit. This all-pervading *conatus* I would call the simplest, because the most universal, and therefore, relatively, a *conatus* and subject of enormous extent. Now, every element or atom of which a tree is composed has its own *conatus* and its own subject. To suppose that these respective and differing intensities of *conatus* and their subjects are annihilated during the time that they are making up a tree is to suppose the annihilation of the tree whilst it exists. But as all these various forces make up but one subject, it is clear that there must be one *conatus* that controls the whole, and which makes all the other forces yield it service. This whole subject now becomes the vehicle for the all-governing *conatus*, because in its government it makes up of all the other forces and their subjects what we call in this illustration a tree. And we know nothing of the all-pervading *conatus* of a tree excepting as it manifests itself in the effects which its subject produces. Nor could all the *conatus* that make a tree from within subsist as a tree without the reaction of *conatus* from without, that is, from atmospheric air, &c. Hence, if there be no vehicle or subject there is no *conatus*, and if there be a *conatus* there must be a vehicle or subject, and if there be a subject there must be action and reaction. All the subjects of nature afford an illustration of what I have called the government of compound *conatus* by an all-pervading simple one of enormous extent. And further, the more a subject consists of compound forces of strong intensity the more it is capable of making itself manifest to the senses. And the less the subject of a *conatus* is compounded, whether small or large, the less it can make itself sensibly manifest.

The general uses of the air we breathe are well known. It is equally well known that the air is the vehicle of what we call sound. *Conatus* acting in and through the air produces vibrations. But these vibrations are not sound until this *conatus* by the vibrations of the air has affected another subject and produced the reaction of the ear. Then as the *conatus* and the subject of the ear harmonize sound is manifest. It is plain that if the vehicle of the vibrations is removed sound cannot exist, or if we can conceive of the *conatus* of the vibrations existing without the air, it cannot make itself known. Further, if vibrations are made in the air for the production of sound, and another order of vibrations, as it were, crosses them so that a crest of one wave coalesces with the depression of another, no sound can be produced. But just as sound could not exist without air so also without it this silence could not be produced. And further, in the production of sound the law of the squares of distance is observed, and that for a reason which I think will shortly appear. Atmospheric air, however, is not a simple subject, for many *conatus* act in it. Hence it is a substance to that degree manifest to the senses, and we are so far physically conscious of its existence. But if atmospheric air be not a simple subject of enormous size, then it may be controlled and permeated by something more simple and more enormous.

Because the undulatory theory of light explains more of its phenomena than the emission theory, the former has been adopted. This undulatory theory assumes the existence of another medium than atmospheric air called luminiferous ether. Of this ether we are in no physical sense conscious, though there are the most substantial reasons for the assumption of its existence, reasons sufficiently cogent to make its existence a fact. If we were unconscious of the undulatory activity of the air we should have to resort to the assumption of such a subject and its activity to explain the production of sound, for in every way light produces its effects as sound does. The magnet and luminosity prove the presence of some vehicle or subject when atmospheric air is absent. Hence atmospheric air neither assists in the formation or the production of light, therefore the substantial reason for assuming another medium that *conatus* may produce light. Light then does not exist apart from the vibrations of luminiferous ether, yet these vibrations do not produce light until they are arrested by a reactionary subject. The capability of this ether, then, is to create from a luminous force acting within it, a force of vibrations so as to produce after reaction the effect called light. Now, it is obvious that the capabilities of the atmospheric air cannot produce light, nor can the capabilities of luminiferous ether produce sound. Hence the two media must be totally different in their constitution. But though this is so it is equally evident that this ether pervades atmospheric air everywhere. I have said respecting a tree that if any of the subordinate *conatus* of it should overpower the government of the pervading one, the tree, in proportion to such resistance and its continuance, comes to an end. And that the vibrations of the air can be so made as to destroy the effects of each other and so annihilate the cause of sound. Similarly the vibrations of luminiferous ether can be made to neutralize each other and from light to produce darkness. And as in the vibrations of atmospheric air the law of the squares of distances holds good, so also it obtains as strongly if not more perfectly in luminiferous ether, for the production of light, heat, magnetism, or electricity. But we are physically unconscious of the presence of luminiferous ether, and this must be so if it approaches nearer to a simple subject of an enormous size, though if it be such a subject its *conatus* must be more potent than atmospheric air, and its constitution more simple.

But neither the one nor the other nor both of them combined are the cause or the reason why they surround the earth everywhere. This cause under certain modifications may be said to originate in the earth herself. These modifications I now come to discuss. The earth, according to her density, I take to be the expression of the *conatus* thereof. And the fulness of her density is the fulness of her *conatus*. This *conatus*, like every other, acts within its subject for its production, maintenance, and manifestation. The subject, then, so far as the earth is considered, is the earth's density taken as a whole. But if we say density is a subject we simply say that force is a subject, for where there is no force there is no density. But if density be the result of force then the density of a thing will be exactly proportional to the various forces within the various atoms of a subject to press themselves together. Hence, there will be as many kinds of density as there are forces or intensities of *conatus*, and these will be manifest in their subjects whether simple or compound. But the more compounded the subject the more it is sensibly manifest or the more it is what is called substance. But just as the various elements of a tree are held together by an all-pervading *conatus*, so the totality of the *conatus* that are in the various elements of the earth are pervaded by a common *conatus*, and this common or universal *conatus* is manifest in the earth herself as the subject. This common or terrestrial *conatus* is exerted within and throughout the earth for her individual preservation as the subject of it. But if nature be uniform in her mode of operation this common terrestrial and earth preserving *conatus* must by means of its subject be able to produce something beyond the subject, and this something must reach to and affect other subjects. As *conatus* by means of air affects the ear and produces sound as luminosity by means of luminiferous ether produces light on subjects, so the preserving *conatus* of the earth must reach to and affect other subjects and produce some effect. What is this effect excepting what is called gravitation or the power of drawing exterior things to herself? And if this be the exterior product or *conatus* in contradistinction to her own interior *conatus* there must be a vehicle through which it operates. It is well known that the gravitating power of the earth not only reaches to the moon, but to the sun and all the planets. What is the vehicle through which such an effect is accomplished? It is equally well known that all the planets have their respective gravitating influences and so affect the earth, each other, and the sun. But the supreme gravitating power in our system originates in the sun.

Now, I wish it to be distinctly understood, that the *conatus* or force to produce density within each member of the solar system in the way I have described, is considered as applying itself absolutely and solely to the maintenance and the individuality of each planet or of the sun. From such consideration it will follow that the maximum of this *conatus* is found within the limit of the orb. Or, if this be not so, then this *conatus* has more than one subject or vehicle, and more than one effect, namely, more than the production of density, which is inconsistent with the maintenance of individuality. The region in which the gravitating power of the sun and planets is exercised is supposed to be devoid of density, that is, devoid of all substance or subjective matter. Hence we arrive at the conclusion that an exterior *conatus* is created by the interior *conatus* of the sun and planets which has no subject or vehicle, and this happens where there ought to be the most simple and powerful subject of the most enormous extent. If this be so, nature is most unlike herself in her greatest extent, and in her most wonderful operation. But let us assume the existence of such a subject. If it be of the simplest kind, as it must be, then it can only be affected in one way, and lie utterly beyond the recognition of mere sense. The one way in which I assume this universal subject or medium to be affected is the way in which it receives and reacts on the internal *conatus* of all the members of the solar system. This exterior *conatus* will be at its maximum of receptivity and reaction in the periphery of each orb, and at its minimum in the boundary of the solar system. The *conatus* for density and individuality reaches its greatest force in the same periphery; therefore it will happen that the highest result of this action and reaction will take place. And this highest result is what I call gravitation, which attains its maximum at the periphery of the heavenly bodies. But I also assume that this assumed universal medium has a *conatus* of its own, independent of the produced *conatus* for gravitation, and that it is a uniform, constant, all-pervading and never-failing effort of persistence and resistance which no other, excepting the *conatus* of the sun and planets, can affect. Hence every other *conatus* must bow to its force and obey its law. And I take this to be the reason why the law of the squares of distance is found to prevail in the forces of the air and of luminiferous ether, as well as in every part of the solar system. That is to say, the resistance of this assumed medium is equal to the squares of the distance of the sun and planets acting upon it, and its disturbance is the disturbance of gravitation.

In consequence of the constant and universal persistence of this assumed *conatus* and its medium force of a different kind, that is, the force which produces motion, can act uniformly throughout it according to its own *conatus*, just as our own bodies can move about in the pressure of atmospheric air, and nothing can affect the force of motion excepting that which produces the law of gravitation, and this law under certain circumstances the force of motion can overpower and neutralize, as differing undulations in the air or ether can be made to neutralize each other. Hence the force of motion is independent of any *conatus* to produce gravitation, and of course independent of gravitation itself.

Ordinary Meeting, March 8th, 1881.

E. W. BINNEY, F.R.S., F.G.S., President, in the Chair.

"Additions to the paper 'On an adaptation of the Lagrangian form of the Equations of fluid motion'," by R. F. GWYTHER, M.A.

With the permission of the Society I desire to add a few results to those which I communicated to the Society in the paper mentioned above. I treat these results as additional to the paper rather than as a separate communication, because the methods are identical with those used before, and deal with the general case of fluid motion. I hope in a subsequent paper to show how some special cases can be treated so as to obtain simpler results, better capable of being tested by observation.

1. If P be any scalar, so that $D_t P = \dot{P} - (S\sigma\nabla P)$

Then $\nabla D_t P = \nabla \dot{P} - \nabla(S\sigma\nabla P)$

$$= \nabla\dot{P} - V\rho\nabla P - (S\sigma\nabla)\nabla P - (S\nabla P\nabla)\sigma \, ^{*}$$

$$\therefore \nabla D_t P = D_t \nabla P - V\rho\nabla P - (S\nabla P\nabla)\sigma$$

$$\text{and } D_t\nabla P = \nabla D_t P + V\rho\nabla P + (S\nabla P\nabla)\sigma$$

Now any vector δ may be written $l\nabla\phi_1 + m\nabla\phi_2 + n\nabla\phi_3$ whence by applying the above we get

$$D_t\delta = D_t l.\nabla\phi_1 + D_t m.\nabla\phi_2 + D_t n.\nabla\phi_3 + V\rho\delta + (S\delta\nabla)\sigma \ldots\ldots(1)$$

If we put $\delta = \sigma$ we get the formula of Section II. (2).

Also if δ be written $L\frac{\alpha}{H} + M\frac{\beta}{H} + N\frac{\gamma}{H}$ we get

$$D_t\delta = D_t L.\frac{\alpha}{H} + D_t M.\frac{\beta}{H} + D_t N.\frac{\gamma}{H} + LD_t\frac{\alpha}{H} + \&c.$$

$$= D_t L.\frac{\alpha}{H} + \&c. \qquad - (S\delta\nabla)\sigma \ldots\ldots(2)$$

because $$D_t\frac{\alpha}{H} = \frac{d\sigma}{d\phi_1}$$

* Notes on some Quaternion transformations. Proc. Lit. & Phil., Vol. XIX.

Now $V\nabla\sigma$ or ρ can be written $\bar{\Sigma}_1 H.\frac{\alpha}{H}+\bar{\Sigma}_2 H\frac{\beta}{H}+\Sigma_3 H.\frac{\gamma}{H}$.

$$\therefore\ D_t\rho = D_t\log H.\rho-(S\rho\nabla)\sigma. \quad\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Imagine ρ also written $\rho = H(l_1\nabla\phi_1+l_2\nabla\phi_2+l_3\nabla\phi_3)$

$$\therefore\ D_t\rho = D_t\log H.\rho + H(D_tl_1.\nabla\phi_1+D_tl_2.\nabla\phi_2+D_tl_3.\nabla\phi_3)+(S\rho\nabla)\sigma$$

whence $D_t\rho - D_t\log H.\rho = \frac{H}{2}\left\{ D_tl_1.\nabla\phi_1+D_tl_2.\nabla\phi_2+D_tl_3.\nabla\phi_3\right),$

$$\text{or } 2D_t\frac{\rho}{H} = D_tl_1.\nabla\phi_1 + \&c.\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

These formulæ enable us to find convenient forms for certain expressions, giving the manner of the motion. Thus

$$D_tS\frac{\sigma\rho}{H} = SD_t\sigma.\frac{\rho}{H}+S\sigma D_t\frac{\rho}{H}$$

$$= S(\nabla D_tP + V\rho\sigma + \overline{S\sigma\nabla}\,\sigma)\frac{\rho}{H} - S\sigma S\overline{\frac{\rho}{H}\nabla}\,\sigma \text{ by (1)}$$

$$= S\nabla D_tP.\frac{\rho}{H}\ \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

since

$$S(\rho S\sigma\nabla - \sigma S\rho\nabla)\sigma = SV.\overline{V\rho\sigma\nabla}\,\sigma = SV\rho\sigma\nabla\sigma = 0$$

and generally

$$S(\rho S\delta\nabla - \delta S\rho\nabla)\sigma = 0\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

whatever vector δ may be. Again

$$D_t\frac{S\sigma\rho}{H} = S\dot{\sigma}\frac{\rho}{H} - S\left(\frac{\rho}{H}S\sigma\nabla + \sigma S\frac{\rho}{H}\nabla\right)\sigma$$

$$= S\dot{\sigma}\frac{\rho}{H} - 2S\frac{\rho}{H}(S\sigma\nabla)\sigma. \quad\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Also writing

$$\delta = L\frac{\alpha}{H}+M\frac{\beta}{H}+N\frac{\gamma}{H}$$

as in (2), we get

$$S\delta\nabla = -\left(L\frac{d}{d\phi_1}+M\frac{d}{d\phi_2}+N\frac{d}{d\phi_3}\right)$$

$$\therefore D_tS\delta\nabla = -\left\{D_tL\frac{d}{d\phi_1}+D_tM\frac{d}{d\phi_2}+D_tN\frac{d}{d\phi_3}\right\}$$

$$-\left\{L\frac{d}{d\phi_1}D_t+M\frac{d}{d\phi_2}D_t+N\frac{d}{d\phi_3}D_t\right\}$$

$$= S(D_t\delta+\overline{S\delta\nabla}\,\sigma)\nabla + \overline{S\delta\nabla}\,D_t \text{ by (2)}$$

and especially

$$\left.\begin{aligned} &D_t.S\frac{\rho}{H}\nabla = (S\frac{\rho}{H}\nabla)D_t \\ \text{but}\quad &D_t(S\sigma\nabla) = (S\dot{\sigma}\nabla)+(S\sigma\nabla)D_t.\end{aligned}\right\}\ \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

The equation (6) shows a curious theorem in the kinematics of vortex motion, connecting the relative velocities of points near a vortex line.

The equation may be written $S\rho(Sx\delta\nabla)\sigma = S\delta(Sx\rho\nabla)\sigma$ where we shall consider, for the moment, that ρ and δ are unit vectors—since we may divide by the product of their tensors. The theorem may be stated thus. If O be any point on a vortex line at which σ expresses the velocity, and if equal small distances (x) be taken in the directions of ρ and of any vector δ; the velocities relative to that at O are $-x(S\rho\nabla)\sigma$ and $-x(S\delta\nabla)\sigma$, and are such that their components resolved along δ and ρ respectively are equal to one another. If the vector δ be one which moves with the fluid (as $\frac{\rho}{H}$) we may then state the theorem of the actual relative motions, for we could write the equation

$$S\frac{\rho}{H}D_t\delta = S\delta D_t\frac{\rho}{H}.$$

Similarly $\frac{1}{2}D_t(T\delta)^2 = S\delta(S\delta\nabla)\sigma =$ the projection of the relative velocity upon δ itself; and $-V\delta(S\delta\nabla)\sigma$ is the vector expressing the double of the rate at which areas are described by the vector δ. If we operate upon this with D_t we get $-V\delta(S\delta\nabla)D_t\sigma$

If we project the double area found above on the plane perpendicular to ρ we get

$$-S\rho\delta(S\delta\nabla)\sigma \div T\rho \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

$$\text{But } -S\rho\delta(S\delta\nabla)\sigma = S\delta.\rho\overline{S\delta\nabla}\sigma = S\delta.\delta\overline{S\rho\nabla}\sigma + S\delta V\overline{V\rho\delta\nabla}\sigma$$
$$= S\delta V\rho\delta\nabla\sigma - S\delta\overline{S\rho\delta\nabla}\sigma$$
$$= (V\rho\delta)^2 - S\delta\overline{S\rho\delta\nabla}\sigma$$

Suppose, for convenience, that ρ, unless when distinctly derived from σ, stands for $U\rho$, a unit vector.

Then $$-S\delta\overline{S\rho\delta\nabla}\sigma = S\rho V\rho\delta\overline{S\rho\delta\nabla}\sigma$$

$=$ $-$twice the rate of description of projected areas by the vector $V\rho\delta$. And we have the theorem that double the sum of the areas described by the small vectors δ and $VU\rho\delta$ is $T\rho(T\delta)^2\sin^2\theta$, where θ is the angle between δ and ρ. It must, however, be noticed that $V\rho\delta$ will not move with the fluid.

Taking δ as before to be a vector moving with the fluid and writing $\delta = l_1\nabla\phi_1 + l_2\nabla\phi_2 + l_3\nabla\phi_3$ we get

$$D_t\delta = D_tl_1.\nabla\phi_1 + \&c. \qquad + V\rho\delta + \overline{S\delta\nabla}\sigma \text{ by } (1) = -(S\delta\nabla)\sigma.$$

$\therefore$ the displacement at the extremity of δ is

$$-\overline{S\delta\nabla}\sigma = \tfrac{1}{2}V\rho\delta + \tfrac{1}{2}(D_tl_1.\nabla\phi_1 + D_tl_2\nabla\phi_2 + D_tl_3\nabla\phi_3)$$

Of these terms on the right the first denotes rotation about an axis $\frac{\rho}{2}$; for the second we will write $\frac{1}{2}\delta^1$. Let ε be a second vector moving with the fluid, and ε^1 be the vector corresponding to δ^1. Then the condition that the part of the strain corresponding to δ^1 may be pure is that δ^1 may be self conjugate,* or that $S\epsilon\delta^1 = S\delta\epsilon^1$.

We have $\delta^1 + V\rho\delta + 2\overline{S\delta\nabla}\sigma = 0$

$$\epsilon^1 + V\rho\varepsilon + 2\overline{S\varepsilon\nabla}\sigma = 0.$$

$$\therefore S\epsilon\delta^1 - S\epsilon^1\delta = S\delta V\rho\epsilon - S\varepsilon V\rho\delta + 2S(\delta S\epsilon\nabla - \epsilon S\delta\nabla)\sigma$$
$$= 2S\delta\rho\epsilon + 2S\delta\epsilon\rho = 0.$$

There are generally three principal axes of strain which are at right angles; from the equations of condition which are $V\delta\delta^1 = 0$ we get for these axes

$$\frac{D_tl_1}{l_1} = \frac{D_tl_2}{l_2} = \frac{D_tl_3}{l_3} = \frac{D_tl}{l} \text{ say} \qquad (10)$$

If δ and ε represent two of these principal axes

$$D_tS\delta\epsilon = SD_t\delta\varepsilon + S\delta D_t\epsilon = -S\epsilon\overline{S\delta\nabla}\sigma - S\delta\overline{S\epsilon\nabla}\sigma = S\delta\epsilon^1 = S\delta^1\epsilon$$

and since ε^1 is parallel to ε, and $S\delta\epsilon = 0$, the principal axes remain at right angles, and therefore remain principal axes.

As this is important, we will give another proof of it:—

δ may be written $l\,(\kappa_1\nabla\phi_1 + \kappa_2\nabla\phi_2 + \kappa_3\nabla\phi_3)$ where $D_t\kappa = 0$ by (10), and δ^1 may be written $D_tl\,\{\kappa_1\nabla\phi_1 + \kappa_2\nabla\phi_2 + \kappa_3\nabla\phi_3\}$.

For shortness write $\delta = l\zeta$, $\delta^1 = D_tl.\zeta$

$$\therefore D_tV\delta\delta^1 = VD_t\delta\delta^1 + V\delta D_t\delta^1,$$
$$= V\{(D_tl.\zeta + lD_t\zeta)D_tl.\zeta - (D_t^2l.\zeta + D_tl.D_t)l\zeta\}$$
$$= 0.$$

* Hamilton's Elements of Quaternions, III. 2—6, and passim.

whence we may conclude that a principal axis remains a principal axis.

We may, therefore, now suppose that we have chosen surfaces ϕ intersecting in principal axes of strain at the points under consideration, as the surfaces to which we are referring the circumstances of motion, and we must show that these sets of surfaces will indicate the principal axes at other points. We might, perhaps, conclude this from the fact that any scalar operation of $V\delta\delta^1$ produces a zero result; but we will show the surfaces of reference intersect at right angles at consecutive points.

In the case considered $\alpha = k_1\nabla\phi_1$, &c. $S\alpha\beta = S\nabla\phi_1\nabla\phi_2 = 0$, &c.

$$\therefore \frac{d}{d\phi_3}S\alpha\beta = S\frac{d\alpha}{d\phi_3}\beta + S\alpha\frac{d\beta}{d\phi_3}$$

$$= \frac{dk_1}{d\phi_3}S\nabla\phi_1\beta + k_1 S\frac{d}{d\phi_3}\nabla\phi_1\beta + k_1 S\nabla\phi_1\nabla\phi_3\frac{d}{d\phi_3}\nabla\phi_1$$

$$- k_1 S\overline{\nabla\phi_1}|^2\frac{d}{d\phi_3}\nabla\phi_3$$

$$= 0$$

with similar results for the other expressions. There is, therefore, one and only one set of surfaces which move with the fluid and cut everywhere orthogonally, and these intersect in the principal axes of strain at every point.

It will be noticed that the quantity k_1 written above may be shown $= \frac{H}{h_1^2} = \frac{(T\alpha)^2}{H}$, and that $H^2 = h_1^2(T\alpha)^2 = h_1^2 h_2^2 h_3^2$.

When using these surfaces as those of reference expressions, such as $\nabla\rho$ undergo considerable simplification.

If in (9) δ had been a principal axis, we should have obtained

$$-S\rho\delta S\overline{\delta\nabla}\sigma = \tfrac{1}{2}S\rho\delta(V\rho\delta + \delta^1) = \tfrac{1}{2}(V\rho\delta)^2 = \tfrac{1}{2}(T\rho)(T\delta)^2\sin^2\theta,$$

and as will be seen later ρ is one of these principal axes only when $V\rho D_t\rho = 0$, or when ρ moves parallel to itself.

2. In certain cases we may simplify considerably the expressions which we have found.

Thus if $(S\rho\nabla)\sigma=0$, a case which includes that of straight parallel vortex filaments,

$$\text{then } D_t\frac{\rho}{H}=0, \text{ and by (4) } \frac{\rho}{H} \text{ may be written}$$

$$l_1\nabla\phi_1+l_2\nabla\phi_2+l_3\nabla\phi_3 \text{ where } D_t l=0.$$

In this case by (6) we have $S\rho\overline{S\delta\nabla}\sigma=0$ or $S\rho D_t\delta=0$, or the relative motion is perpendicular to ρ.

Also by (7) $D_t\left(S\sigma\frac{\rho}{H}\right)=S\dot{\sigma}\frac{\rho}{H}$; $=S\nabla D_t P.\frac{\rho}{H}$; and $D_t S\frac{\rho}{H}\delta=0$,

and $\nabla\frac{\rho}{H}$ moves with the fluid as $\frac{\rho}{H}$ does.

A more general case, namely, when $(S\rho\nabla)\sigma^2=0$ gives very similar results. It may be written $S\sigma\overline{S\rho\nabla}\sigma=0$ or $S\sigma D_t\rho=0$, and is the case when the tensor of the velocity is constant along a vortex line, including the case of an ordinary vortex ring.

We deduce by (6) that $S\rho\overline{S\sigma\nabla}\sigma=0$,

and obtain $D_t\left(S\sigma\frac{\rho}{H}\right)=S\dot{\sigma}\frac{\rho}{H}$ as before.

If $S\sigma\overline{S\rho\nabla}\sigma=0$ at any point of a vortex ring, it denotes that at that point σ^2 is a maximum or a minimum.

Another case in which we get some additional simplification is when the vortex line through any point moves parallel to itself. In this case

$$V\rho D_t\rho=0 \text{ or } V\rho\overline{S\rho\nabla}\sigma=0$$

where we may omit the H or not, as we please.

Write as in (4) $\frac{\rho}{H}=l_1\nabla\rho_1+l_2\nabla\rho_2+l_3\nabla\rho_3$

$$\text{Then because } V\frac{\rho}{H}D_t\frac{\rho}{H}=0,$$

$$\frac{D_t l_1}{l_1}=\frac{D_t l_2}{l_2}=\frac{D_t l_3}{l_3}=\frac{D_t l}{l} \text{ say}$$

$$\therefore\ l_1=lk_1, l_2=lk_3, l_3=lk_2 \text{ where } D_t k=0$$

$$\text{and } \frac{\rho}{H}=l(k_1\nabla\phi_1+k_2\nabla\phi_2+k_3\nabla\phi_3\}$$

$$2D_t\frac{\rho}{H}=D_t l\left\{k_1\nabla\phi_1+\&c.\right\}=D_t\log l.\frac{\rho}{H}.$$

we have further that $S\nabla\rho=0$.

and may deduce that $D_t\dfrac{T\rho}{lH}=0$

To investigate another case, let us suppose that $T\rho$ increases or decreases in every direction except that of ρ. The condition for this is that $\overline{S\rho\delta\nabla}.\rho^2=0$ where δ is any vector whatever.

But $S\rho\,\overline{S\rho\delta\nabla\rho}=.S\rho^2\delta\nabla\rho-S\rho V.\overline{V\rho\delta\nabla}.\rho$

$$=S\rho^2\delta\nabla\rho-S\rho^2\overline{S\delta\nabla\rho}+S\rho\delta\overline{S\rho\nabla\rho}$$

$$=S\delta\rho^2\nabla\rho-S\delta\rho\overline{S\rho\nabla\rho}.$$

And this will not be zero for all directions of δ unless $\rho^2\nabla\rho$ $=V\rho\overline{S\rho\nabla\rho}$ or unless $V\rho\nabla\rho^2=2.\rho S\rho\nabla\rho=0$ *

This condition would have to hold if the vortex motion existed only in an indefinitely thin filament, and was either a maximum or a minimum at some point within it.

Another case: suppose that the surface ϕ_1 contains vortex lines, and that $T\rho$ increases or diminishes as the surface ϕ_1 is crossed on either side

Then $S\rho\overline{S\nabla\phi_1\nabla\rho}=0$.

But $S\rho\overline{S\nabla\phi_1\nabla\rho}=S\nabla\phi_1\overline{S\rho\nabla\rho}+SV.\overline{V\rho\nabla\phi_1.\nabla}.\rho$

$$=S\nabla\phi_1\overline{S\rho\nabla\rho}+SV\rho\nabla\phi_1.\nabla\rho$$

$$=S\nabla\phi_1(\overline{S\rho\nabla\rho}-V\rho\nabla\rho)$$

$$=\tfrac{1}{2}S\nabla\phi_1\nabla\rho^2.=0$$

This condition must be satisfied at points in a vortex sheet or at points in a thin vortex filament if it contains a thread of fluid not affected by the vortex motion, or if the vortex motion is a minimum within.

3. It has been shown (Section II.) that σ may be written $\nabla P+\nabla\Sigma_1\nabla\phi_1+\Sigma_2\nabla\phi_2+\Sigma_3\nabla\phi_3$, but the whole portion $\Sigma_1\nabla\phi_1$ $+\Sigma_2\nabla\phi_2+\Sigma_3\nabla\phi_3$ will not generally contribute towards producing rotation; for supposing $\Sigma_1=\dfrac{dQ}{d\phi_1}$ we may write this portion as $\nabla Q+\Sigma_2\nabla\phi_2+\Sigma_3\nabla\phi_3$, or generally we may write $\sigma=\nabla P+\xi$, where $\xi=\Sigma_2\nabla\phi_2+\Sigma_3\nabla\rho_3$. In this we have made no

* Notes on some Quaternion transformations.

special choice of the surfaces ϕ, but since ρ moves with the fluid in such a way that if the two surfaces ϕ_2 and ϕ_3 intersect in vortex lines at any time, they will continue to intersect in the same lines, we may choose the surfaces ϕ_2 and ϕ_3 so as to intersect in vortex lines, and therefore put $\overline{\Sigma}_2 = 0$, $\overline{\Sigma}_3 = 0$ and $\rho = \overline{\Sigma_1}\alpha$. Whence $\dfrac{d\overline{\Sigma}_1}{d\phi_1} = 0$, or, the strength of the vortex is constant as we pass along the filament—a proposition generally proved by the aid of Green's Theorem.

Also $S\xi\rho = 0$ and $S\sigma\rho = \overline{\Sigma}_1 S\alpha \nabla P = -H\overline{\Sigma}_1\dfrac{dP}{d\phi_1}$.

The first of these equations shows that the axis of rotation is perpendicular to the part of the velocity essential to the rotation.

4. Or we might by a proper choice of the surfaces ϕ_1 express ξ merely as $\Sigma_1 \nabla \phi_1$, and since $D_t\Sigma = 0$, this would remain as the proper form of σ. This form of σ expressed as $\nabla P + \Sigma_1 \nabla \phi_1$ seems that most applicable to the usual Cartesian notation; comparing it with the usual form for irrotational motion we see that two new scalars are introduced, connected by the two scalar equations $D_t\Sigma_1 = 0$, $D_t\phi_1 = 0$.

$$\text{or } \dot{\Sigma}_1 - \Sigma_1 S \nabla \phi_1 \nabla \Sigma_1 = S \nabla P \nabla \Sigma_1$$
$$\text{and } \dot{\phi}_1 - \Sigma_1 (\nabla \phi_1)^2 = S \nabla P \nabla \phi_1$$

These two equations show very clearly that with a certain definite system of vortex motion a definite irrotational velocity must exist accompanying it, and that if any extraneous velocity could be imposed upon the system, the velocity must in some way be modified, and react upon the disturbing velocity.

The fact that σ may be written as $\nabla P + \Sigma_1 \nabla \phi_1$ seems to me sufficiently important to make me introduce the theorem in Pure Mathematics on which it depends: namely, that the ordinary differential equation $Pdx + Qdy + Rdz$ consists always of the sum of two parts—one immediately integrable, the other integrable by a factor.

Let dF be the integrable part. Then

$$\left(\mathrm{P}-\frac{d\mathrm{F}}{dx}\right)dx+\left(\mathrm{Q}-\frac{d\mathrm{F}}{dy}\right)dy+\left(\mathrm{R}-\frac{d\mathrm{F}}{dz}\right)dz$$

is integrable by a factor if

$$\frac{d\mathrm{F}}{dx}\left(\frac{d\mathrm{Q}}{dz}-\frac{d\mathrm{R}}{dy}\right)+\frac{d\mathrm{F}}{dy}\left(\frac{d\mathrm{R}}{dx}-\frac{d\mathrm{P}}{dz}\right)+\frac{d\mathrm{F}}{dz}\left(\frac{d\mathrm{P}}{dy}-\frac{d\mathrm{Q}}{dz}\right)$$

$$=\mathrm{P}\left(\frac{d\mathrm{Q}}{dz}-\frac{d\mathrm{R}}{dy}\right)+\mathrm{Q}\left(\frac{d\mathrm{R}}{dx}-\frac{d\mathrm{P}}{dz}\right)+\mathrm{R}\left(\frac{d\mathrm{Q}}{dx}-\frac{d\mathrm{P}}{dy}\right)$$

But this is an ordinary linear partial differential equation, from which F can be found as a function of x y and z by Lagrange's method, and, therefore, a function F can always be found such that $\mathrm{P}dx+\mathrm{Q}dy+\mathrm{R}dz-d.\mathrm{F}$ is integrable by a factor.

5. Returning to the form of $\sigma=\nabla\mathrm{P}+\xi$ we see that

$$\mathrm{D}_t\sigma=\mathrm{D}_t\nabla\mathrm{P}+\mathrm{D}_t\xi$$

$$=\left(\frac{d}{dt}-\overline{\mathrm{S}(\nabla\mathrm{P}+\xi)\nabla}\right)\nabla\mathrm{P}+\mathrm{V}\rho\xi+\overline{\mathrm{S}\xi\nabla}\rho \text{ by 1}$$

$$=\left(\frac{d}{dt}-\overline{\mathrm{S}\nabla\mathrm{P}\nabla}\right)\nabla\mathrm{P}+\mathrm{V}\rho\xi+\overline{\mathrm{S}\xi\nabla\xi}$$

$$=\left(\frac{d}{dt}-\overline{\mathrm{S}\nabla\mathrm{P}\nabla}\right)\nabla\mathrm{P}+\tfrac{1}{2}\nabla\xi^2.*$$

Where if ξ did not exist $\mathrm{D}_t\sigma$ would be $\left(\frac{d}{dt}-\overline{\mathrm{S}\nabla\mathrm{P}\nabla}\right)\nabla\mathrm{P}$ showing that the accompanying irrotational motion is one capable of existing by itself, while the essentially rotational portion is not generally capable of so doing; and that $\mathrm{D}_t\sigma$ is not $\mathrm{D}_t\nabla\mathrm{P}(\xi=0)+\mathrm{D}_t\xi(\nabla\mathrm{P}=0)$.

6. If we find the angle between the axis of rotation at any point and at a distance x along the filament, we may deduce a measure of the curvature of the filament, and by taking a corresponding length on an axis perpendicular to the osculating plane we may form a vector of curvature at the point.

* Notes on Quaternion transformations.

Thus the angle between ρ and $\rho - x\,\overline{\mathrm{SU}\rho\nabla}\rho$ is $\dfrac{x\mathrm{TV}\rho\overline{\mathrm{SU}\rho\nabla}\rho}{\mathrm{T}\rho^2}$

whence the vector of curvature is $\dfrac{\mathrm{V}\rho\overline{\mathrm{S}\rho\nabla}\rho}{\mathrm{T}\rho^3}$

in which we may substitute from the formula,

$$\nabla\rho^2 = 2\mathrm{V}\nabla\rho\rho + 2(\mathrm{S}\rho\nabla)\rho.$$

This vector will give us the curvature at any point and also the torsional movement at that point during the motion. It however contains $\nabla\rho$, and can only be applied in special cases where the expressions can be simplified.

In order to express the torsional motion of a vortex line at any point we will write $\mathrm{U}\rho = \rho_1$ and the vector of curvature as ϵ. Then $\epsilon = \mathrm{V}\rho_1\overline{\mathrm{S}\rho_1\nabla}.\rho_1$. ....(11)

Then $\mathrm{V}\epsilon\mathrm{D}_t\epsilon$ will be a vector denoting the rate of torsion of the vortex line at the point considered during the motion.

$$\therefore \mathrm{V}\epsilon\mathrm{D}_t\epsilon = \mathrm{V}\epsilon\{\mathrm{VD}_t\rho_1\overline{\mathrm{S}\rho_1\nabla}.\rho_1 + \rho_1\overline{\mathrm{S}\rho_1\nabla}.\mathrm{D}_t\rho_1)$$
$$= \overline{\mathrm{S}\rho_1\nabla}.\rho_1\mathrm{S}\epsilon\mathrm{D}_t\rho_1 - \rho_1\mathrm{S}\epsilon\overline{\mathrm{S}\rho_1\nabla}.\mathrm{D}_t\rho_1.$$

This vector, of course, vanishes if $\mathrm{D}_t\rho$ is parallel to ρ; a case which has been considered.

The general case in which it vanishes is when

$$\epsilon = \mathrm{VD}_t\rho\overline{\mathrm{S}\rho\nabla}.\mathrm{D}_t\rho:$$

in all other cases there will be a torsional flexure at each point in the vortex line.

An expression for the radius of torsion of the vortex line at any time could also be found, but it is more complex than that already found, and would be of doubtful use in any case of application. We have already introduced two quantities $\overline{\mathrm{S}\rho\nabla}\rho$ and $\nabla\rho$ for which we have found no proper expression, and of which the second is not easily interpretable.

In the case considered above when $\mathrm{T}\rho$ decreases or increases in every direction round the vortex line, we have the simpler expression that $\epsilon = -\dfrac{\nabla\rho}{\mathrm{T}\rho}$, with the condition that $\mathrm{S}\epsilon\rho = 0$.

If the vortex filament is straight we have in this case $\nabla\rho=0$, which is an important condition in the case of fluid friction. On this account we should learn in what cases $\nabla\rho$ moves with the fluid.

Writing $\frac{\rho}{H}=l_1\nabla\phi_1+l_2\nabla\phi_2+l_3\nabla\phi_3$ as in (3), we can find that

$$D_t\nabla\frac{\rho}{H}=V(\nabla D_t l_1.\nabla\phi_1+\nabla D_t l_2\nabla\phi_2+\nabla D_t l_3.\nabla\phi_3)-(S\nabla\frac{\rho}{H}\nabla)\sigma+\Delta\frac{\rho}{H}.S\nabla\sigma$$

$$=2V\nabla D_t\frac{\rho}{H}-(S\nabla\frac{\rho}{H}\nabla)\sigma.+S\nabla\sigma.\frac{\Delta\rho}{H} \text{ by (4).}$$

and therefore the condition that $\frac{1}{H}\nabla\frac{\rho}{H}$ may move with the fluid is that $V\nabla D_t\frac{\rho}{H}=0$.

7. The general case of motion of a viscous fluid is not capable of being simplified by the method of this paper, as no convenient expression can in general be found for $\nabla\rho$. As, however, there are cases in which simplifications can be made, I shall consider some of these cases.

In the first case I shall suppose the fluid incompressible, as it is convenient to take these cases separately; and also suppose the filaments to be straight and parallel at right angles to the plane of motion.

The equation of motion is

$$\nabla D_t P+D_t\Sigma_1\nabla\phi_1+D_t\Sigma_2\nabla\phi_2+\nabla V+\frac{\mu}{d}\nabla\rho=0$$

From this equation we will now suppose all terms of the form ∇V removed, so that we remain with

$$D_t\Sigma_1\nabla\phi_1+D_t\Sigma_2\nabla\phi_3+\frac{\mu}{d}\nabla\rho=0$$

$$\text{But } \rho=\overline{\Sigma}_3\alpha=\overline{\Sigma}_3T\alpha.\nabla\phi_3=\overline{\Sigma}\nabla\phi_3$$

when $\nabla\phi_3$ is now a unit vector perpendicular to the plane of motion.

$$\therefore \nabla\rho=V\nabla\overline{\Sigma}.\nabla\phi_3.$$

If the filament be such that $T\rho$ is a maximum or minimum along it, we have shown that $\nabla\rho=0$, we must therefore have $D_t\Sigma=0$, or the nature of the motion is not affected by the viscosity.

Next, taking the general case of such filaments, we have always

$$D_t\bar{\Sigma}_1.\nabla\phi_1 + \&c. \qquad + \frac{\mu}{d}T\rho.\epsilon = 0$$

which shows that the vector $D_t\Sigma_1.\nabla\phi_1 + \&c.$ is proportional to $T\rho$ directly and to the radius of curvature of the filament inversely.

The only equation which we are able to obtain from this form of equation follows from $S\epsilon\rho = 0$

$$\text{whence } \bar{\Sigma}_1 D_t\Sigma_1 + \bar{\Sigma}_2 D_t\Sigma_2 + \bar{\Sigma}_3 D_t\Sigma_3 = 0.$$

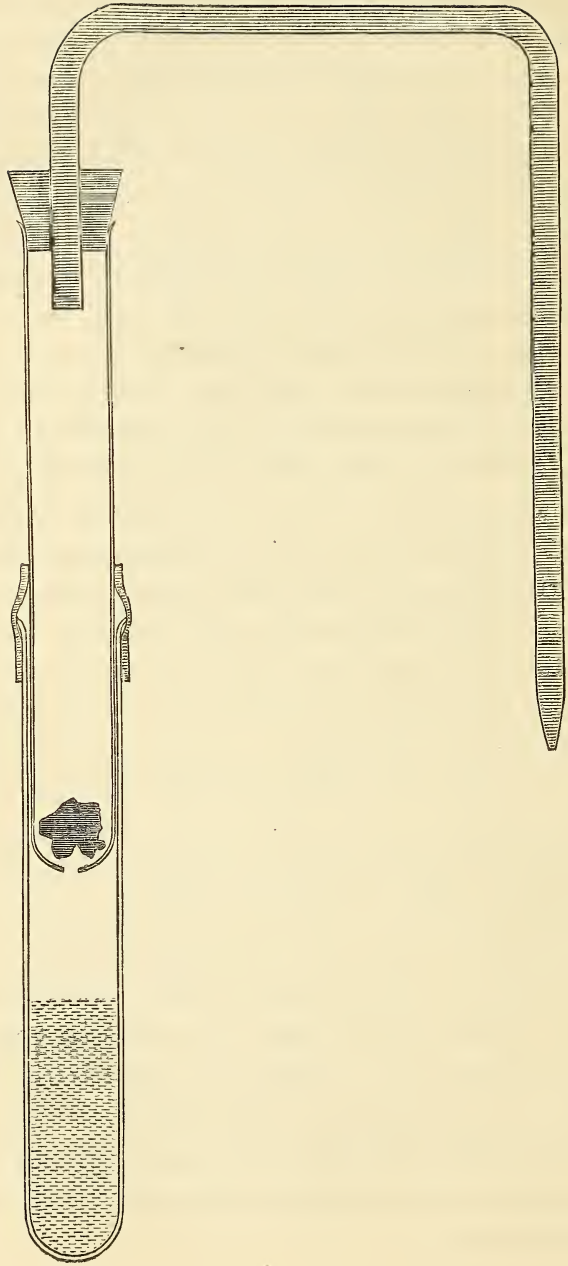
From the equation $V\rho\nabla\rho^2 = 0$, we can not draw any conclusion as we have no convenient expression for $\nabla\rho^2$.

Turning to the terms which the elasticity of a viscous fluid introduces, namely, $\frac{\mu}{d}\nabla D_t\log H.$ and noticing that by the equation of continuity $d = H\phi$, where $D_t\phi = 0$, we see that the elasticity will generally give rise to vortex motion in a viscous fluid; and that the condition that it may not do so is that $H\phi$ may be some function of $D_t\log H$.

"A Sulphuretted Hydrogen Apparatus," by Peter Hart, Esq.

When hydric sulphide is only occasionally required, and then in small quantities, an apparatus which so furnishes it is useful, especially when it can be used repeatedly without washing out or replenishing. The one I have contrived seems to me to fulfil these conditions. There have been many invented, but they mostly require either many joints or especially formed pieces of glass. This one can be made by any one possessing only very small skill in fitting up apparatus. It consists of two test tubes, the larger of *one* inch internal diameter, the other of such smaller diameter as to slide easily without friction into the larger. This smaller tube is by means of the blowpipe perforated at the bottom with a quarter-inch hole and is also provided with a rubber stopper and a gas leading tube bent twice at right angles. The larger tube has a piece of rubber tube two inches in length, and of rather smaller diameter than itself, pushed over its mouth, one inch on the tube and one inch projecting. This completes the apparatus. To work it fill the larger tube from one third to one half full of a mixture of sulphuric acid and water—one part acid, three parts water. Drop a lump of iron sulphide into the smaller tube, insert the stopper with leading pipe firmly into this, and thrust its lower perforated end through the rubber mouth of the larger tube, pushing it down until it reaches the acid, and allowing sufficient of this to enter the perforation to cover the sulphide iron. Gas immediately commences to be evolved and can be bubbled through the solution to be examined. When sufficient has been obtained, raise the upper tube until the lower end is out of the acid, the remains of which at once drain away from the sulphide and all action ceases, or practically so. It is only necessary to hang up the apparatus until again needed, when, by heating the end of the lower tube containing the acid over a Bunsen burner, and pushing down the upper, it commences full action again. This can be repeated until the acid becomes saturated, or so much so as to require replenishing.

Of course it need not be limited to the dimensions I have named. A much larger upper tube might be employed, which, combined with a suitably sized lower bottler would furnish gas enough for a quantitative analysis. By occasionally sinking the upper tube deeper into the acid the stream may be fairly regulated, sufficiently so at all events for ordinary work.



A letter was read from SAMUEL CROMPTON, Esq., M.D., &c., accompanying a fine series of photographs of distinguished astronomers, and of the principal astronomical instruments of the Paris Observatory, which he had received from Admiral Mouchez, the Director of the Observatory, and which he now sent for inspection in the belief that they would be interesting to the members of the Society.

"Note on an attempt to analyse the recorded Diurnal Ranges of Magnetic Declination," by BALFOUR STEWART, M.A., LL.D., F.R.S., Professor of Natural Philosophy at the Owens College, and WILLIAM DODGSON, Esq.

1. It is well known that Professor Rudolph Wolf has endeavoured to render observations of sun spots made at different times, and by different observers, comparable with each other, and has thus formed a list exhibiting approximately the relative sun-spot activity for each year. This list extends back into the seventeenth century, and is unquestionably of much value. Nevertheless, it must be borne in mind that we possess no sun-spot data sufficiently accurate for a discussion, in a complete manner, of questions relating to solar periodicity before the time when Schwabe had finally matured his system of solar observations, which was not until the year 1832.

We have, however, a much longer series of the diurnal ranges of magnetic declination. Now, these are already well known to follow very closely all the variations of sun-spot frequency, being greatest when there are most, and least when there are fewest spots, and it may even be imagined that such ranges give us a better estimate of true solar activity than that which can be derived from the direct measurement of spotted areas.

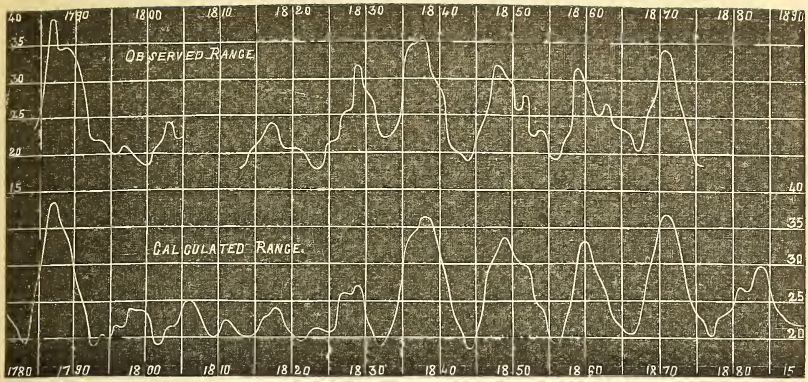
The long-period inequalities of the diurnal range of magnetic declination are thus, we may imagine, precisely those of solar activity, so that to analyse the former is probably equivalent to analysing the latter.

2. Our method of analysis is not new. The system pursued by us is, in fact, that which has been pursued by Baxendell, and probably other astronomers, with observations of variable stars, and it has already been applied by one of us in a preliminary manner to magnetic declination ranges (Pro. Lit. and Phil. Society, Manchester, February 24, 1880).

3. The observations at our disposal are those which have been used by Prof. Elias Loomis in his comparison of the mean daily range of the magnetic declination with the extent of the black spots on the surface of the sun.* These observations are recorded as monthly means of diurnal declination range, and we found it necessary to multiply each by a certain factor, firstly, on account of the well-known annual inequality of declination range, and secondly, to bring them all to the standard of the Prague observations. We have applied for this latter purpose precisely the same corrections as those made by Professor Loomis.

4. The result of an analysis of these observations has been to indicate the existence of three inequalities; two dominant ones with periods of about $10\frac{1}{2}$ and 12 years, and a subsidiary one with a period of about $16\frac{1}{4}$ years. By these means we have been enabled to reproduce the observed annual values of declination range with an average difference of 39″. The amount of agreement between the observed and calculated values will be seen from a diagram which accompanies this note. We are, however, of opinion that the series of observed values at present obtainable is too short to render this analysis a very accurate one. It will certainly not bear carrying back forty or fifty years beyond its starting point, which was in 1784, and it would

* American Journal of Science and Arts, Vol. L., No. CXLIX.



be very hazardous to carry it forward any considerable length into the future. We may, however, mention that our calculations indicate a maximum of declination range about 1884, but not so pronounced a maximum as that of 1871.

5. During our analysis an observation was made by us which we think worthy of record.

It is a well-known fact that the so called eleven-yearly oscillations of declination range are at certain times large, and at other times small. Thus, for instance, they have been large for the last forty years, but they were small about the earlier part of the present century. It is clear to us from an inspection of the observations, that a series of large oscillations is accompanied with an exaltation of the base line, or line denoting average efficiency, while a series of small oscillations is accompanied with a depression of the same. The result is a long-period curve of the base line, the bent period, so to speak, of the eleven-yearly inequality.

Now, a phenomenon precisely similar occurs in connexion with shorter periods. If we take inequalities having a period of three or four months, we find that such are alternately well developed or of large range, and badly developed or of small range; and that a large range of such is accompanied with an exaltation of the base line or line of average efficiency, while a small range is accompanied with a depression of the same. The result is a curve of the base line of which the period is roughly speaking eleven years. May we not therefore imagine that the so-called eleven-yearly period or, to speak more correctly, the ten and a half and twelve-yearly periods into which the eleven-yearly period may perhaps be analysed, may be in reality bent periods for shorter disturbances? Is it not therefore possible that a study of these shorter periods may give us information regarding the nature of the eleven-yearly period, whether for sun spots or declination ranges, which the small series of actual observations is incompetent to afford?

We beg to take this opportunity of thanking Mr. William Stroud for the help he has given us in this investigation.

Ordinary Meeting, March 22nd, 1881.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

Three electric kites used by the late Mr. Sturgeon were presented to the Society by Mr. James Dancer, and the thanks of the Society were voted to the Donor.

"On the Growth and Use of a Symbolical Language," by Mr. Hugh McColl, B.A. Communicated by the Rev. Robert Harley, M.A., F.R.S.

This paper discusses in a general way the cases in which symbols may be advantageously employed in logical and mathematical reasoning, and endeavours, from an examination of our existing stock of symbols, to deduce some rules or guiding principles, first, as to when new symbols should be introduced, and secondly, as to what kinds of symbols should be selected. It also contains a brief account of the gradual development of the author's own symbolic method, as explained and set forth in his papers published in the *Proceedings of the London Mathematical Society*, the *Educational Times*, the *Philosophical Magazine*, and *Mind*.

The President exhibited to the meeting four original letters of the late Mr. Thomas Carlyle, addressed by him to the late Mr. Samuel Bamford of Blackley, the Author of the "Passages in the Life of a Radical."

5, Chayne Row, Chelsea,
London, 13 April, 1843.

Dear Sir,

Will you be so good as send, by the earliest convenience you have, two copies of your Book, *Bamford's Life of a Radical*; addressed to "The Hon. W. B. Baring, 12, Gt. Stanhope Street, London." Two copies have been wanted there for some time. Probably you have some appointed conveyance by which your Books arrive here without additional cost; if so, pray use the earliest of these. Nay, perhaps your Books are themselves procurable somewhere in London? That would be the shortest way of all. At any rate the Coach or Railway remains; and will be of no enormous amount. Be so good as apprise me by post what way you have adopted; and on what day the Books may be looked for in Stanhope Street;—not forgetting to enclose an *account* withal.

I read your Book with much interest; with a true desire to hear more and more of the authentic news of Middleton and of the honest toiling men there. Many persons have a similar desire. I would recommend you to try whether there is not yet more to be said, perhaps, on some side of that subject; for it belongs to an important class in these days. A man is at all times entitled, or even called upon by occasion, to speak, and write and in all fit ways *utter*, what he has himself gone thro', and *known*, and got the mastery of;—and in truth, at bottom, there is nothing else that any man has a right to write of. For the rest, one principle, I think, in whatever farther you write, may be enough to guide you: that of standing rigorously by the fact, however naked it look. Fact is eternal; all Fiction is very transitory in comparison. All men are interested in any man if he will speak the facts of his life for them; *his* authentic experience, which corresponds, as face with face, to that of all other sons of Adam.

Another humbler thing I will suggest: that it seems to me a pity you had not your Book in the hands of some Bookseller; such a one could sell it for you much faster than you yourself will. A friend of mine, for example, could not find your Book in Liverpool at all; and, unless he have written to Middleton as I suggested, may still be in fruitless search of it. The Commission charges of Booksellers are in truth entirely exorbitant, unexampled among any other class of *sellers* or salesmen in the world: but as I said once, "if you have a waggon to drive to York, you had better pay the tolls, however unconscionable, than try to steeple-hunt it thither!"—This too is not to be neglected, tho' a very secondary side of the business.

Wishing you right good speed in all manful industry with hand or with head or with heart,

I remain,

Yours very truly,

T. Carlyle.

P.S. What is curious enough: this Note was just folded, but not yet sealed, when your letter was handed in to me! Many thanks for your gift. Your remarks on *Chartism* are also very welcome to me. I have now only to add that you had better send Mr. Baring's two copies to Mr. Ballantyne along with the other, and request him to forward them all to me without delay. Do not forget to enclose your account; which will be paid thro' the Post-Office.

T. C.

The Grange, Hampshire,
4 Sept^{r}, 1848.

My dear Sir,

Both the Nos. of your new work, which you were so kind as send me, came safely to hand,—the last only a few days before our leaving Chelsea for this place, whither we have come to see some friends, and have a little fresh air while the summer still lasts. I have read the two Pieces with great pleasure, in which Mrs. C. your old acquaintance also shares: we find the Narrative full of rough veracity; clear, wholesome, description of what you meant it to describe,—namely, of an authentic phasis of Human Life;—in which accordingly all human creatures may take a real interest. Withal there is a certain breezy freshness in the delineation,—as indeed in former delineations by the same hand: a rustic honesty, a healthy manful turn of mind is nowhere wanting, and that is a pleasant neighbour everywhere, and to all readers and all men. On the whole, if you continue this Work in the way you have begun, I think there is every reason to expect a lasting favour for it, and all manner of good fruit that you and your friends could have anticipated. There are only two precepts I will bid you, once more, always keep in mind: the first is to be *brief*; not to dwell on an object one instant *after* you have made it clear to the reader, and on the whole to be *select* in your objects taken for description, dwelling on each in proportion to its likelihood to interest, *omitting* many in which such likelihood is doubtful, and only bringing out the more important into prominence and detail. The second, which indeed is still more essential, but which I need not insist upon since I see you scrupulously observe it, is, to be *exact* to the truth in all points; never to hope to mend a fact by polishing any corner of it off into fiction, or adding any ornament which it had *not*, but to give it us always as God gave it,—that, I suppose, will turn out to be best state it *could* be in! These two principles, I think, are the whole law of the matter: and in fact they are the epitome of what a sound, strong and healthy mind will, by Nature, be led to achieve in such an enterprize; wherefore perhaps my best "precept" of all were, to recommend Samuel Bamford to his own Good Genius (to his own honest *good sense* and healthy instincts) and bid him write or omit without misgivings whenever *that* had clearly spoken! And on the whole, persevere and prosper: that is the wish we form for you.

We are here among high people, to whom the *Passages* and other writings of yours are known: last night I was commissioned by Lord Lansdown to ask you to send him a copy of this new work,—or to bid Simpkin and Marshal send it, if that can be done; but in any way to be sure that he gets it soon. I think perhaps you had better send it direct yourself; if the two Nos. are stitched together, they will go thro' the Post-Office for sixpence (six stamps stuck on them); the address is, The Lord Marquis of Lansdown, Lansdown House, London;—and you have only to write a little Note (a *separate* Post-office Note) saying, with your address given, that the Book is sent by my order, that you yourself both write and sell it, and that the price is so and so. Pray do not *neglect* this, however; but set about doing it straightway.

If you write at any time to Chelsea, the letter finds me after one day's delay.

My wife bids me remember her to you and Mrs. Bamford, whom she hopes to see again by and by; Blakely appears to be a place very bright in her recollections.

With many good wishes, I remain
sincerely yours
T. Carlyle.

Chelsea, 9 Jan[y], 1849.

My dear Sir,

Yesternight I read the Preface and the last portion of your Autobiography. I have followed the work throughout, as the successive instalments of it reached me by your kindness (for which I am much obliged); and now it is ended, handsomely, yet sooner than I quite expected. It seems to me you have managed the affair very well indeed: a manful rustic frankness runs thro' it; a wholesome freshness, energy, sincerity: it is very clear everywhere, very credible; and, to sum up many merits in one, it is singularly *memorable,* and stands out in distinct visibility and continuity, in one's mind after reading it. You will give an innocent and profitable pleasure, I hope, to very many persons by what you have written; and make known, with advantage to all parties, important forms of human life, in quarters where they have not been known hitherto, and much required to be known.

On the whole, however, we must not yet let you off, or allow you to persuade yourself that you have done with us. A vast deal more of knowledge about Lancashire operatives, and their ways of living and thinking, their miseries and advantages, their virtues and sins, still lies in your experience;—and you must endeavour, by all good methods, to get it *winnowed,* the chaff of it well separated from the wheat, and to let us *have* the latter, as your convenience will serve. To workers themselves you might have much to say, in the way of admonition, encouragement, instruction, reproof; and the Captains of Workers, the rich people, are very willing also to listen to you, and certain of them will believe heartily whatever true thing you tell them: this is a combination of auditors which nobody but yourself has such hold of at present; and you must encourage yourself to do with all fidelity whatever you can in that peculiar and by no means unimportant position you occupy. "Brevity, sincerity,"—and in fact, all sorts of manful *virtue,*—will have once more, as they everywhere in this world do, avail you.

Since I wrote last, I have never seen Lord Lansdowne; know not what he did with those Nos. of your Book, or indeed whether he has ever yet fairly got hold of them,—for his life all this while has been in the country, I suppose, amid a crowd of guests, and with little leisure for considerate reading. Pray tell me how the matter is, when you next write.—I wish you farther to address a copy of your Book, so soon as you have got it bound, to Lord Ashburton, whose address I enclose: if the Book is under half a pound weight, it will go by post if you stick sixpence worth of stamps upon it; above a pound and under two, it goes for a shilling's worth. And the Note you write must bear a cover quite apart. With many good wishes

Yours

T. Carlyle.

Chelsea, 21 April, 1849.

My dear Sir,

It will not, I fear, be of much use to try a Bookseller with the *Poems*: Poetry of all kinds is a bugbear to the Booksellers at present, for there is no kind of Poetry that they find the Public will buy. For my own part too, I own, I had much rather see a sensible man, like you, put down your real thoughts and convictions in Prose, than occupy yourself with fancies and imaginations such as are usually dealt with in verse. The time is in deadly *earnest*; our life itself, in all times, is a most earnest *practical* matter, and only incidentally a sportful or *singing* or rhyming one:—Let S. Bamford continue to tell us in fresh truthful *prose* the things he has learned about Lancashire and the world; that, I must say, would be my verdict too!

Lord Lansdowne has hardly come across me again at all,—I think only once,—since he commissioned me to bid you send your Book. In the huge whirlpool of things great and small, which the like of him lives in, he has doubtless let the transaction go out of his head; and had not you, according to my bargain with you, recalled the memory of it, all had remained forgotten. I have now communicated with his Lordship; and probably before long you will hear some farther account of it from him or me.

Yesterday Lord Ashburton sent me the enclosed Draft of Twenty-five Pounds, which I was in some handsome way to present to you as a proof of his approbation. On being consulted, I had said there was a Public Testimonial set on foot for your behoof some time ago; to which, tho' it was no longer open to the public at large, his Lordship might still fitly contribute whatever acknowledgment of service he thought due to you. This Draft is the result;—which any Manchester Banker who knows *you*, or knows a responsible man going *with* you to his Bank, will at once convert into cash;—after which, pray be so good as signify that you have received the amount, and that all is safe.

With many good wishes

Yours very sincerely

T. Carlyle.

Mr. Bamford, Blakeley.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

February 14th, 1881.

ALFRED BROTHERS, F.R.A.S., President of the Section, in the Chair.

It was determined that the Section recommend the Parent Society to confer with the Government with a view to obtaining a gratuitous copy of the Reports and Memoirs now being issued in connection with the "Challenger" expedition.

"On Pendant Nests of a Gregarious Moth from Venezuela," by Mr. JOHN PLANT, F.G.S.

Entomologists have long been familiar with insects which are social or gregarious either in the larva, pupa, or perfect stages of their metamorphoses, and it appears from the results of many recent careful investigations that although a social instinct has been found more or less developed in insects belonging to every order, yet it is in the Hymenoptera that we find the highest instincts for forming and living in communities and society. "The bees and the ants are a wise and perfect people" is an adage as old as historic time.

The lepidoptera are not known to include any species which live in entire communal life in every stage; the caterpillars of some species will associate for feeding, such as Clisiocampa neustria, Eriogaster lanestris, and others, which live in a tent-like nest when in the stage of larva, and enlarge it as necessity compels. The common silk moth, Bombyx mori, is gregarious as a larva, and can be trained to group their cocoons in bundles of twigs; but these species form no communities when in the perfect stage, they simply pair off and are entirely independent of each other. Other species there are which will be independent when in their larval stage, yet will instinctively band together to construct a common nest, pouch, or tent, in which they gregariously undergo their transformation into the stage of pupæ, again dispersing in pairs when they pass into perfect insects. Others there are which are not known to live gregariously either as larvæ or pupæ, which are yet observed flying in extraordinary swarms as perfect butterflies and moths—so that whilst communistic habits are displayed in one or two of the successive stages of transformation in lepidopterous insects, they always fall short of the complete communistic life as seen in the bees, ants, wasps, termites, locusts, and even gnats and mosquitoes. But for the history and details of these marvellous creatures I would refer the student to Kirby and Spence, Introduction to Entomology; Dr. P. Martin Duncan, The Transformation of Insects; Sir John Lubbock's works on The Ants; and the Rev. J. G. Wood, Homes without Hands, and Insects at Home.

There are several small lepidoptera in our own country which build nests in common, or weave some kind of case of silk, leaves, or twigs, in which the cocoon will find shelter and warmth during the season of rest. These tents and pendulous nests are comparatively small and inconspicuous, but they are not the less curiously made and well adapted for the purposes they have to fulfil.

It is from the tropical forests of South America, Africa, India, &c., that the greatest samples of gregarious nests have been obtained, and of which I have four good examples to lay before the Section.

I have exhausted the sources of reference which are at my command for some information about these specimens, without having met with any description that will apply to them. There are descriptions of various forms of pendant gregarious nests of insects in the authors' works I have mentioned, and in other works on Entomology the general habits of moths and butterflies to gregarious habits are amply dwelt upon—but nothing I have seen as yet describes these curious nests.

Mr. Wood, in his Homes without Hands, page 441, figures and describes the social nests of two species of lepidoptera, one of which bears a fair resemblance to the specimens I exhibit. His sample came from Mexico; it is a pendulous nest about eight inches long, having a flask-like shape; the outside is made of a dull whitish parchment-like, hard, stiff, and tough material, with an inside lining of softer texture. When cut open the pupæ, to the number of more than one hundred, were seen suspended by their tails with a silken thread round the upper part of the nest as well as to the twig which ran from the top down the interior. The pupæ were not in any exact order—the nest had a small hole at the bottom through which the perfect insect would escape. All the pupæ were dead and shrivelled up, but Mr. Westwood succeeded in identifying the species after he had carefully softened portions of the membranous wings so as to display the true forms of their nervures and cells—it proved to belong to the family of the Heliconoïd moths, named *Eucheira socialis*.

The other nest is from tropical Africa, and is the only specimen known. It forms a large tent over the branch of a tree. Nothing is known of the species, and it is most probably the gregarious tent of a moth.

Humboldt describes a moth also found in Mexico—*Bombyx Modrono*—which is gregarious, the larvæ uniting to form a goodish sized nest of a dense tough material and brilliant whiteness, from the lining and cocoons of which the natives procure a supply of silk of a soft fair quality.

The nests which I exhibit are, I believe, allied to the species just described, but they possess some peculiar features which he does not allude to, and which would scarcely have escaped his notice had the nests of *B. Modrono* possessed them.

These nests were brought by Mr. James P. Spence with his extensive collection of natural history objects from Venezuela, which it will be remembered were exhibited in the Society's rooms December, 1872. I obtained them when the collection was subsequently sold. As there is no description of them in his MS. list beyond "Nests of a caterpillar unknown,' it is not at all safe to affirm that they came from any part of Venezuela, as he made purchases of curiosities from travellers and agents from other parts of South and Central America, and these may as likely as not have come from Mexico.

The nests are somewhat irregularly pouch-shaped, and have each been constructed from an attachment first formed upon the bough of a tree. The length varies in each, being six, eight, and eleven inches. The external case is evidently made from a vegetable paste or pulp which when dry makes a tough sort of felted cartridge paper, very light and smooth in texture, such a material as would be made with the masticated vegetable food consumed by the caterpillars, which we see used in the habitations of many other species of insects.

The outside of the nest is beautifully impressed with outlines of leaves which must have been fixed and pressed upon the pulp when it was yet soft and adhesive. Portions of these leaves still remain attached to the nests, and the species can to some extent be identified. Several species of British moths and butterflies are in the habit of enclosing the pupa and cocoon in an extra case or nest, by drawing together the edges of a large leaf until it completely enshrouds the cocoon; but the larvæ which form these large tropical nests spread out whole leaves and gum them firmly to the nest. Probably it arises from an instinctive precaution against enemies, for the leaves would completely hide the nest, yet add nothing to its strength.

On cutting the nest open from end to end the interior is seen to be closely packed with a lightish brown mass of silk within which can be found a good number of cocoons, varying according to the size of the nest. The cocoons are enveloped in the silk in rows of two or more, some ranged from end to end in rows side by side, and others in irregular files from end to end, but all very tightly packed in the mass of silk. A cocoon case measures a little over an inch long, so we can judge the perfect moth to be about the size of the British "Oak Egger moth," *Lasiocampa Quercûs*, with wings stretching about 2½ inches. I have searched in vain for a pupa sound enough to dissect; they are all dried up and shrivelled within the unbursted cocoons. The outer fibres of the silk adhere firmly to the interior of the nest, and mixed with the silk near the end are numbers of eggs of the moth, proving that some of the cocoons had burst and the moth escaped.

The nest has small openings at each extremity for the escape of the moth, and the hole where it is attached to the bough.

I cannot detect any evidence about the nests which would lead us to think that they are formed gradually piece by piece over any length of time like the nests of wasps, bees, and ants. On the other hand, they are evidently begun and completed in a short time, when the larvæ are approaching their full growth, when instinct impels a number of them to band together and rapidly construct a common shelter and retreat in which to await the strange dormant stage of their existence.

They must proceed to masticate and make a vegetable pulp in sufficient quantity to form the covering to their common nest, and be able to decide its capacity to hold their whole number. The strong leaves must be applied whilst the pulp is yet soft and sticky, and the outside completed before a retreat is made to the interior—then the larvæ must emit each length of the silken thread, and fill the nest to the full; and lastly, each larva must take up its proper rank, spin for itself a delicate cerecloth around its changing form, and entomb itself to wait the final change which gives it a renewed and almost seraphic life; truly it is a marvellous episode in the life of a gregarious caterpillar.

Upon consideration of all the features and evidences presented in my research I do not hesitate to say, that I believe the larvæ which construct these and similar nests, are the larvæ of a moth belonging to the great family of Bombycidæ, perhaps the Bombyx Humboldt has mentioned as being found in Mexico.

There is another specimen of a nest upon which Mr. Spence has written a ticket, "inner layer of a nest of Gregarious Caterpillars, species not known." As there is no such lining to be found in the three nests just described, I conclude it must have been obtained from a different kind of nest, though it is quite probable the nest was one made by a gregarious moth; it is fourteen inches long, eight inches circumference in the middle, tapering sharply at each end, it has been pendant like the others. The material is a thin sort of skin of brown colour, wonderfully like some of the common Japanese-made papers. There is no doubt of its having been stripped without difficulty from the inside of a stiff pendant nest, as it was held to the sides only by silken web. This nest when complete and hanging from the bough, would look like a long and somewhat elegant flask.

March 14th, 1881.

Alfred Brothers, F.R.A.S., President of the Section, in the Chair.

Mr. M. M. Hartog, B.Sc., F.L.S., exhibited a Seiss' camera lucida.

He also exhibited some slides illustrating the segmental organs of the Leech.

Mr. R. Ellis Cunliffe brought before the Section's notice a copy of the first volume of the "Challenger" expedition.

Mr. Plant, F.G.S., exhibited a glass bottle filled with large black ants from Baltimore, U.S.A. They were all still alive, though somewhat torpid.

Mr. James Cosmo Melvill, F.L.S., exhibited some very curious forms of fresh water mollusca from Lake Tanganyika, Central Africa, which had been collected in 1879-80 by Mr. E. Coode Hore, of the Central African Mission. Mr. Edgar A. Smith, of the Zoological Department, British Museum, had described the new species; and it was found necessary to create three new genera for as many species, in the case of Tiphobia Horei, Neothauma Tanganyicense, and Syrnolopsis lacustris. The first of them, T. Horei, is the most remarkable fresh water mollusc yet discovered. It bears more resemblance to the marine Gasteropod Murex Brandaris, or Tudicla spirillus, than to any fresh water genus, if we except the strange Melaniad Io spinosa, and its allies. The animal and operculum of Tiphobia being yet unknown, it is placed provisionally by Mr. Smith among the Melaniadæ. Neothauma Tanganyicense is, perhaps, only a Paludina; there are certain peculiarities about the lip, however, which show affinity with the Melaniadæ, and the texture of the shell is not so light as most of the Paludinæ. It resembles P. umbilicata from Siam, and P. Ingallsiana from Japan. Specimens of these and other close allies were exhibited. Syrnolopsis lacustris, a small elongate Melaniad, with flexuose lip, calls for no especial remark.

Mr. Melvill also exhibited several other shells, most of them new species of Lake Tanganyika shells, but none of them new genera, *e.g.*, Spatha Tanganyicensis (Smith), Melania nassa (Woodward), Lithoglyphus rufofilosus (Smith), L. zonatus (Wd.); but regretted that he had found it quite impossible to obtain any specimens of the curious Limno trochus of Smith, a recently-described genus containing two species, L. Thomsoni and L. Kirkii, bearing great external resemblance to the Trochidæ, or the Littorinoid genus, Risella. They are shells of greater finish and granulation than is usual in fresh water genera.

The great extent of this lake, or rather inland sea, is no doubt one reason for its producing quasi-marine mollusca, and in a short time we shall probably be startled by more curious and undreamt-of forms. It will be difficult, however, to eclipse the Tiphobia Horei for singularity of appearance. There is a good plate of this species and others in the November number of Zoological Proceedings (1880).

Errata.

Page 101, line 7 from bottom, and page 102, line 7 from top for "bent" read "beat."

Ordinary Meeting, April 5th, 1881.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

"On Du Bourguet's 'Calcul' and on Ternaries," by Sir James Cockle, F.R.S, Corresponding Member of the Society.

1. In "Notes and Queries" for June 12, 1880 (6th S., No. 24, vol. I., pp. 469, 470), I have given a further bibliography of Du Bourguet's 'Calcul', a work on which I have already commented (*ante*, vol. xix., pp. 9, 10; 181, 182).

2. Doubting Du Bourguet's calculations, so far as they relate to his example (*b*), I communicated with Mr. Robert Rawson who, in a letter to me dated May 3rd, 1880, replied that he found, after going over the work twice, that the criterion of integrability for (*b*) becomes

$$(z-y-x)^{\frac{1}{3}}-\frac{ax}{4}(z-y-x)^{-\frac{1}{12}}+\frac{bx}{3}=0,$$

and that Du Bourguet's result is obtained by leaving out the first term from the above equation.

3. Mr. Rawson's result will be verified if in Art 9 (*infra*) we put $m=\frac{1}{3}=r$ and $n=\frac{1}{4}$.

4. This seeming error of Du Bourguet may perhaps be corrected by treating the x which multiplies the cube root in the coefficient of dy (*ante*, vol. xix., p. 9) as a misprint for some constant, say c. If so, we get

$$c\left(\frac{a}{4u^{\frac{1}{12}}}-\frac{b}{3}\right)=\frac{cbx}{3u^{\frac{1}{12}}}\left(\frac{3a}{4b}-u^{\frac{1}{12}}\right)=0,$$

wherein $u=z-y-x$, and his conclusion follows. Du Bourguet's theorem may be paraphrased thus, viz., "a factor of U (the criterion of integrability being U=0) may yield a solution if equated to a constant."

5. The theorem however does not cover the whole ground, for if V be a variable function $U+V=0$ may give a solution. This is an easy deduction from (p. 116 of) a paper of mine cited in Art. 7 (*infra*).

6. In my paper "On Ternary Differential Equations" (*ante*, vol. xvi., pp. 66—68), in connection with which that of Mr. Rawson, bearing the like title (*ib.*, pp. 114—118), should be read, $\frac{D}{dx}$ and $\frac{D}{dy}$ must be interpreted as follows, viz.:

$$\frac{D}{dx}=\frac{d}{dx}+p\frac{d}{dz},\ \frac{D}{dy}=\frac{d}{dy}+q\frac{d}{dz},$$

and this being done, (3) is an equation which becomes an identity if, in the sinister, we replace p and q by M and N respectively, or operate *vice versâ* on the dexter. In what follows I recur to my paper.

7. At p. 115 of a memoir printed in the Proceedings of the London Mathematical Society (vol X., pp. 105—120) I have in effect shown that

$$(N-q)\frac{dM}{dz}(M-p)\frac{dN}{dz}=U \ldots\ldots\ldots\ldots\ (7).$$

This numbering (7) is, and is intended to be, consecutive to that of my paper on ternaries, and does not occur in the memoir.

8. Subtracting (7) from (3) we get

$$\frac{DM}{dy}-\frac{DN}{dx}=0 \ldots\ldots\ldots\ldots\ldots\ldots\ (8),$$

and we get this same (8) by transposing the sinister of (7) to its dexter.

9. Comparing (3), (7), and (8), we see that U vanishes when z is eliminated by means of $M=p$ or $N=q$.

10. Let $z-y-x=u$ and $M=1+u^m(1+au^n-bu^r)$, $N=1+xu^m$;

$$\text{then } \frac{dM}{dy}+N\frac{dM}{dz}=mxu^{m-1}(M-1)+xu^{2m}(nau^{n-1}-rbu^{r-1}),$$

$$\frac{dN}{dx}+M\frac{dN}{dz}=u^m+(M-1)mxu^{m-1},$$

$$U=-u^m+xu^{2m}(nau^{n-1}-rbu^{r-1}).$$

11. When m, n, and r are positive, $u=0$ is a solution of (1) Yet the positive values of m, n, and r may be such as, while making $u=0$, to make $\mathrm{U}=\infty$. This is a paradox. But U contains the term $mxu^{m-1}(\mathrm{M}-1)(1-1)$, which is suppressed in the above calculation. Now, although this suppression is in general allowable, it may (but will not necessarily) cease to be so when the above term takes the form $\infty(1-1)$. It would therefore seem that $\mathrm{X}-\mathrm{X}$ is not necessarily null when X is infinite.

12. The $\infty(1-1)$ will not occur unless one at least of the quantities $\frac{d\mathrm{M}}{dz}$ and $\frac{a\mathrm{N}}{dz}$ be rendered infinite. The general theorem is (not that of Du Bourguet but) this, viz., Retain in the calculation of U all terms whatever, whether they seem to cancel one another or not. Write the result in the form $\mathrm{U}=\square+\mathrm{X}(1-1)$. Then $\square=0$, or, failing that, $\mathrm{X}=\infty$ (which can only arise from $\frac{d\mathrm{M}}{dz}=\infty$ or $\frac{d\mathrm{N}}{dz}=\infty$) may yield a single solution.

2, Sandringham Gardens,
Ealing, near London, W.

March 30, 1881.

The PRESIDENT said that he had, on several occasions, brought before the Society a notice of the Eucalyptus *globulus* growing near to the sea in his garden at Douglas in the Isle of Man. It was planted in 1875, and grew about 7 feet in height annually during the three following years; after these its top reached higher than the wall sheltering it, and it was exposed to the east winds from the sea, which stopped its rapid growth. It now has attained a height of thirty feet. During the present winter it fared pretty well until the beginning of March, when the strong gales made bad work with its foliage, but the tree is still alive, and he has every hope it will rally again in the summer. It grows about six feet above the ordinary high water mark of the sea in Douglas Bay.

"Note on the Presence of Arsenic in Paper Hangings," by HARRY GRIMSHAW, F.C.S.

That arsenic in various states of combination is very often present in the colouring matter of paperhangings is a very well ascertained fact. That it is not confined, as was at one time generally supposed, to those papers which are coloured green, is also pretty well understood, many chemists having found it in papers of all shades and colours, including even white and grey.

A case which illustrates very well this general distribution of arsenic in papers of various colours and shades, and also illustrates one or two other interesting features in connection with this subject, has been brought under my notice by Mr. R. Le Neve Foster, F.C.S., and it will perhaps be of some little interest to this Society. One of the two series of specimens of wall paper which I now show you consists of six papers of varying colours. Three greens, of different shades, light brown, dark brown, and pink, are the tints comprised, and all of them without exception contain arsenic largely. The pink, which is a very light shade, contains the least arsenic, and the brightest green contains the most, though one of the brown shades contains a very large amount. I have not determined the amount of arsenic quantitatively, as that was not needed to condemn the papers, but probably the pink paper contains a sufficiently large quantity of arsenic on one square foot to poison an adult person.

When these papers were selected from a Lancashire manufacturer it was particularly specified that they should be free from arsenic. The absence of this body was assured in a positive manner, and no doubt the papers would have been definitely guaranteed to be absolutely free from arsenic. This assurance, however, from previous experience, was not relied on, and the papers were qualitatively analysed for arsenic with the result above stated.

The injurious effects which might have resulted, in fact would almost certainly have resulted from papering six rooms in a house with arsenical paperhangings, do not need enlarging upon any more than does the almost criminal foolishness of stating that such papers were free from arsenic.

The second series of six samples which I have placed along with the six arsenical papers illustrates very conclusively the fact that arsenical compounds are certainly not essential to the production of the colours required in the decoration of paper. These second papers were obtained from a London manufacturer to replace those which I have described, and will be seen to be so near them in shade and colour that in one or two cases it is difficult to perceive any difference at all. None of the second series of papers yield the least indication of arsenic with Marsh's test, and therefore entirely justify their warranty as free from arsenic, and were of course selected for use. We have therefore in these six self-tinted papers and the two-patterned papers, which I have also here, tints which alone or in combination will serve to demonstrate that any colour almost which is desired can be obtained without the addition of arsenic. If there is a difference in the appearance of the arsenical and non-arsenical colours, it is that the former are rather brighter. This however is not altogether a merit, for wall colours may very easily be *too bright.*

It is to be regretted that non-arsenical paperhangings are at present, as a rule, somewhat dearer than the ordinary ones, but there is not much reason to doubt that this will be materially changed when the former are more largely made and used than at present. The cheapness of arsenic and its compounds is an unfortunate circumstance which favours its adoption, but when it is more generally acknowledged that the "brightness" yielded by these arsenical colours is not at all indispensable, this cheapness will not be an insuperable objection.

In papers which contain arsenic the hardness of the surface and the comparative firmness with which the colour is fixed on the paper are of course important factors in the danger which attends their use; a paper on which the colour is but loosely attached, though it may contain less arsenic, will be much more dangerous than one containing a much larger amount with the colour firmly adherent, the minimum of danger being reached in a "glazed" paper, or a sized and varnished one. In any case, however, a sensible person will prefer not to live continually surrounded by so many square feet of arsenic-covered walls, and it is to be hoped that the promiscuous use of arsenical paperhangings will receive a permanent check on the completion of the labours of the Committee of the Society of Arts, which is, I understand, at present drafting an Act of Parliament to regulate the application of this poisonous substance, and endeavouring to decide upon a test to which suspected papers may be uniformly subjected.

It is not a point to congratulate ourselves upon, that it appears to be the opinion that the Lancashire paperhanging manufacturers have the unenviable reputation of being greater offenders with respect to the presence of arsenic in papers than their fellows nearer the metropolis, and there can be no necessity, with the local scientific and technological knowledge which is attainable, that this should be the case.

It appears to be a moot point whether the cheaper or the more expensive papers usually contain more arsenic, and also in which class is it oftenest found. I hope to have an opportunity of making a communication to the Society on this point on a future occasion.

Dr. Joule, F.R.S., said that since Mr. Grimshaw read his paper on the sulphuric acid produced by gas lights, he had hung two finely perforated zinc plates over one of his burners. The nearest plate was 12 inches above the flame, the other 3 inches above it. The burner was a large one, and lighted on the average 5 hours each day. The zinc plates were examined after three months, when it was found that the lower one had accumulated the usual brownish black deposit and also a furring of sulphate of zinc. The upper plate of zinc was little affected, which leads him to the belief that a single plate of perforated zinc of about a foot square is sufficient to remove the greatest part of the noxious emanations, and obviates to a great extent the necessity of a globe or chimney.

"On the Relation of Electrical Resistance to the Chemical Composition of Steel Wire," by WILLIAM H. JOHNSON, B.Sc.

I showed in a paper read before the Society in March last year, and entitled "On the Electrical Resistance and its Relation to the Tensile Strain and other Mechanical Properties of Iron and Steel Wire" that in cast steel wires drawn in the same way but manufactured so as to contain different quantities of carbon, etc., the electrical resistance increased with the resistance to tensile strain, *vide* table B in the report of my paper.—Pro. Man. Lit. & Phil. Society, No. 12, vol. XIX.

During the last year Dr. Burghardt has very carefully analysed the identical samples of annealed steel wire whose electrical resistance and other mechanical tests are given in table B just mentioned. The results for all samples with the exception of No. 6, not yet analysed, are shown in table C.

A glance at this table shows us that five of the samples have only four elements other than iron present in quantity, namely,—carbon in two forms combined and graphite; silicone and manganese; and traces only of sulphur and phosphorus.

Now how do these elements effect the conductivity of the steel? Let us examine them in detail.

First, graphite carbon must be present in the steel as a mechanical mixture, and so can scarcely exercise any influence on the conductivity. Then manganese will probably be present in the form of an oxide, as manganese oxidises at the high temperatures steel is cast more readily than any of the other constituents of the steel. Now, oxide of manganese can hardly be present in the steel other than as a mechanical mixture, and thus we may disregard its influence.

There are now left combined carbon and silicon, and in samples 1 and 2 a little sulphur or phosphorus. From analogy with copper, sulphur and phosphorus should increase the electrical resistance of iron very much. Perhaps we may estimate in a rough way the total effect of these elements on the conductivity by taking their sum as shown at foot of table C. If this is correct, we are led to the interesting result that within the range of these experiments any increase in the percentage of sulphur, phosphorus, carbon, and silicon present in a steel is accompanied by an increase in its electrical resistance, and further, an increased electrical resistance is concurrent with an increase in the resistance to tensile strain.

The quantity of carbon, silicon, sulphur, and manganese in the samples of steel is so very small that the most careful analyses give results which must be regarded as approximate rather than definite; hence I have much diffidence in laying these figures before you. But however much the ultimate accuracy of these figures may be called in question, I think we may fairly say that the electrical resistance of a piece of iron or steel is a measure of its resistance to tensile strain and of the amount of combined carbon, sulphur, silicon, and phosphorus it contains.

Table C.

Analysis of Cast Steel Wires, Nos. 1 to 8, and Electrical Tests as given in Table B, Pro. Man. Lit. & Phil. Soc., March, 1880.

Sample No.	1	2	3	4	5	7	8
Metallic Iron............	98·980	99·070	98·870	98·880	99·030	99·170	99·007
Combined Carbon......	·391	·438	·270	·280	·182	·226	·268
Graphite Carbon	·040	·060	·150	·150	·130	·150	·080
Silicon	·157	·011	·190	·150	·140	·080	·033
Manganese...............	·088	·300	·470	·410	·390	·340	·380
Sulphur	·080	·031	trace	trace	trace	trace	trace
Phosphorus	·096	trace	trace	trace	trace	trace	trace
Total	99·832	99·910	99·950	99·870	99·872	99·966	99·768
Combined Carbon, Silicon, Sulphur, and Phosphorus...	·724	·479	·460	·430	·322	·306	·301
Electrical Resistance of annealed Steel Wire in Ohm's per meter gramme	2·140	1·903	1·560	1·519	1·450	1·430	1·070

Errata in Table B, Pro. Man. Lit. and Phil. Society, No. 12, Vol. XIX.

After words "Elongation at moment of fracture," insert "*per cent*" of original length.

PHYSICAL AND MATHEMATICAL SECTION.

Annual Meeting, March 29th, 1881.

E. W. Binney, F.R.S., F.G.S., President of the Section, in the Chair.

The following gentlemen were elected officers of the Section for the ensuing year:—

President.

JOSEPH BAXENDELL, F.R.A.S.

Vice-Presidents.

E. W. BINNEY, F.R.S., F.G.S.

ALFRED BROTHERS, F.R.A.S.

Treasurer.

JAMES BOTTOMLEY, D.Sc., F.C.S.

Secretary.

JOHN A. BENNION, F.R.A.S.

"On the Motion of Developable Cylinders," by James Bottomley, D.Sc., F.C.S.

I have not seen, in any works on Dynamics, the following problem treated. A perfectly flexible surface is rolled up so as to form a cylinder. The external edge is fixed and the cylinder is allowed to roll down an inclined plane, under the action of gravity, to determine the motion. As examples we may take rolls of tape or ribbon. I suppose the lamina to have thickness, but this thickness to be indefinitely small. Approximately the motions may be determined as follows:—Let a section of the cylinder be made by a vertical plane through its centre of gravity. Take fixed point as origin. The external forces acting on the mass are $g\sin a$ and the tension at the fixed point, these act along the plane, which may be taken for the direction of the axis of x; perpendicular to the plane the external forces are $-g\cos a$ and the resistance of the plane—these acting in the direction of the axis of y. Of the whole tension at the fixed point a portion will be due to the unrolled part of the cylinder in contact with the plane, also of the whole resistance of the plane a portion will be due to the unrolled portion. For each particle in contact with the plane $\frac{d^2x}{dt^2}$ and $\frac{d^2y}{dt^2}$ vanishes. If then T_1 denotes the tension due to the rolling mass and R the resistance, the ordinary equations of motion will give

$$\Sigma m\frac{d^2x}{dt^2} = M_1 g\sin a - T_1 \quad \text{........................(1)}$$

$$\Sigma m\frac{d^2y}{dt^2} = -M_1 g\cos a + R_1 \quad \text{..... ....(2)}$$

The summation extending to all the particles of the rolling mass. If we suppose it to move as a rigid body these equations may be written

$$M_1\frac{d^2x}{dt^2} = M_1 g\sin a - T_1$$

$$M_1\frac{d^2y}{dt^2} = -M_1 g\cos a + R_1$$

If we take moments about the centre of the rolling cylinder the equation will be

$$\Sigma m\left\{x\frac{d^2y}{dt^2} - y\frac{d^2x}{dt^2}\right\} = T_1 y$$

Or, more simply, if we suppose the cylinder to move as a rigid body,

$$\frac{d}{dt}\left(M_1 k^2\frac{d\theta}{dt}\right) = T_1 y \quad \text{.. ....(3)}$$

M_1k^2 denoting the instantaneous moment of inertia. From (1) and (3) we have the following equation:—

$$M_1 y\frac{d^2x}{dt^2}+\frac{t}{dt}\left(M_1k^2\frac{d\theta}{dt}\right)=M_1yg\sin a\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Also we have the following geometrical equation, since the space x is described by a circle of variable radius:—$dx=yd\theta$. Also the mass in contact with the plane will be $bdcx$ where c denotes thickness, b and d breadth and density. If we regard the rolling portion as a circular cylinder its mass will be $bd\pi y^2$, supposing it to have the same density as the unrolled portion. Let M be the whole mass, and R initial radius, thus $M=\pi R^2bd$. Since the mass is constant we obtain the equation $\pi y^2=\pi R^2-cx$, since y and x are the coordinates of the centre of gravity, this equation gives a parabola as its locus. Also $k^2=\frac{y^2}{2}$.

Hence equation (4) may be written

$$\frac{d^2x}{dt^2}-\frac{c}{2\pi y^2}\left(\frac{dx}{dt}\right)^2=\frac{2}{3}g\sin a.$$

By integration we obtain

$$\left(\frac{dx}{dt}\right)^2=\frac{1}{(\pi R^2-cx)}\left\{A-\frac{2}{3}\frac{g}{c}\sin a(\pi R^2-cx)^2\right\}$$

A denoting the constant. If this be determined by the supposition that the mass starts from rest, the equation may be written as follows:—

$$\left(\frac{dx}{dt}\right)^2=\frac{2}{3}\frac{g}{c}\sin a\pi R^2\frac{\left\{1-\left(1-\frac{cx}{\pi R^2}\right)^2\right\}}{1-\frac{cx}{\pi R^2}}$$

or if l denotes the length of the tape

$$\left(\frac{dx}{at}\right)^2=\frac{2}{3}g\sin al\frac{\left\{1-\left(1-\frac{x}{l}\right)^2\right\}}{1-\frac{x}{l}}$$

Hence as x approaches to the value l the velocity increases indefinitely. The whole tension at the fixed point at any time will be

$$\frac{Mg\sin\alpha - gM_1\sin\alpha\frac{1}{3}\left\{1+\left(1-\frac{x}{l}\right)^2\right\}}{\left(1-\frac{x}{l}\right)^2}$$

The initial tension will be $\dfrac{Mg\sin\alpha}{3}$

If the external end of the tape were attached to the contiguous coil so that it could not unroll, the tension at the fixed point would be $Mg\sin\alpha$. If the fastening suddenly gave way, the tension would immediately alter and become only one third of its previous value.

If we suppose the length of the tape to be infinite, then the velocity after describing any finite space will be

$$2\sqrt{\frac{g}{3}\sin\alpha . x}$$

If we suppose the motion to take place on a horizontal plane, the equation of motion changes; the differential equation now becomes

$$\frac{d^2x}{dt^2} - \frac{c}{2\pi y^2}\left(\frac{dx}{dt}\right)^2 = 0$$

A first integral of this equation will be

$$\left(\frac{dx}{dt}\right)^2 = \frac{A}{\pi R^2 - cx} \quad \text{.........................(1)}$$

To determine A, suppose the mass set in motion by a blow parallel to the plane so that the initial velocity is V, thus $A = \pi R^2 V^2$.

Substituting, integrating again, and determining the constant, we have

$$t = \frac{2l}{3V}\left\{1 - \left(1 - \frac{x}{l}\right)^{\frac{3}{2}}\right\} \quad \text{..................(2)}$$

To unwind the whole length of the tape, this equation would make the time to vary as the length directly and as the initial velocity inversely.

Equation (1) may also be written

$$M_1\left(\frac{dx}{dt}\right)^2 = MV^2$$

Hence, as the mass diminishes the velocity increases, but the kinetic energy in the direction of motion is constant and equal to its initial value. Hence it would seem that none of the energy of the blow is consumed during the rotation of the variable cylinder; once started it would continue of itself. In the rolled-up cylinder, there is an amount of potential energy which may be estimated as follows: suppose that originally we had a thin lamina resting on a flat plane; now, the amount of work necessary to raise a particle of weight w to the height y is wy; and to raise an aggregate of particles the work will be Σwy or $gM\bar{y}$, where $\bar{y}$ denotes the vertical height of the centre of gravity and M the whole mass. In the rolled-up cylinder this is stored up as potential energy; during the motion it assumes the kinetic form, and would of itself be sufficient to keep up the motion on a smooth plane. In what precedes I have supposed the centre of gravity to lie in the normal to the plane drawn through the point of contact of the cylinder with the plane. This would not be exactly true, on account of the cylinder not being perfectly circular; there will be an extremely small couple due to gravity tending to produce rotation.

If in equation (2) we suppose the length of the tape to be infinite, for the time of motion during any finite length we shall have $t=\frac{x}{v}$.

In the above problem I have supposed the external edge of the tape to be fixed. We may, however, have the internal edge fixed and the external in motion, as in the following problem. An indefinitely thin lamina is wound round a fixed horizontal cylinder of indefinitely small cross section to the external edge of the lamina a weight is fixed to determine the motion of this edge. Suppose we take moments about the fixed axis. Then the expression

$$\Sigma m\left(\frac{xd^2y}{dt^2}-T\frac{a^2x}{dt^2}\right)$$

for the whole mass may be divided into two parts—for the portion that is still coiled up the angular velocity will be the same for each particle, and equal to the angular velocity of the body about the axis. For this portion then we shall have the expression $\frac{d}{dt}\left(\frac{M_1k^2dt}{dt}\right)$. For the unwound portion the angular velocity about the axis is not the same for each particle. At any instant y is the same for each particle, also $\frac{dy}{dt}$ is the same for each particle. The equation of moments for this part will take the form

$$\frac{d}{dt}\cdot\frac{dx}{dt}\left\{\frac{cx}{4y}(R^2+3y^2)\right\}$$

The geometrical equations will be the same as before. The positive direction of the axis of x is taken vertically downwards. Suppose w the attached weight to have n times the mass of the tape, then the equation of motion may be written

$$\frac{d}{dt}\cdot\frac{dx}{dt}\left\{\frac{\pi y3}{2}+\frac{cx(R^2+3y^2)}{4y}\right\}=cxgy+gn\pi R^2y$$

The coefficient of $\frac{dx}{dt}$ may also be written

$$\frac{1}{4y}\left(\frac{2\pi^2R^4-c^2x^2}{\pi}\right)$$

Writing, for brevity, this in the form $F(x)$, the equation of motion becomes

$$\frac{d^2x}{dt^2}F(x)+F^1(x)\left(\frac{dx}{dt}\right)^2=cxgy+gxn\pi R^2$$

The solution of this equation is

$$\left(\frac{dx}{at}\right)^2=\frac{2}{(F(x))^2}\left\{\int gy(cx+n\pi R^2)F(x)dx+c\right\}$$

If we suppose the motion to start from rest, the constant will be 0. Performing the integration, the result will be

$$\frac{dx}{at}=\frac{y}{2-\frac{x^2}{l^2}}\sqrt{\frac{8g}{\pi R^2}}\sqrt{\frac{x^2}{l}+2nx-\frac{nx^3}{3l^2}-\frac{x^4}{4l^3}}$$

If we suppose the length of the tape to be infinite, the velocity, after describing any finite space x, will be

$$2\sqrt{\frac{ngx}{\pi}}$$

Erratum.

Page 104, line 1, for "Chayne" read "Cheyne."

Annual General Meeting, April 19th, 1881.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

Report of the Council, April, 1881.

The Treasurer's Annual Account shows that the balance against the General Fund Account has increased from £57 0s. 2d. on the 1st of April, 1880, to £90 0s. 7d. on the 1st of April, 1881; that the balance in favour of the Natural History Fund Account has increased from £56 10s. 5d. to £76 5s. 8d.; and deducting the difference between these two sums from the Compounders' Fund, £125, there is a balance of £111 5s. 1d. in favour of the Society on the 1st of April, 1881, against a balance of £124 10s. 3d. on the 1st of April, 1880.

The number of ordinary members on the roll of the Society on the 1st of April, 1880, was 157, and one new member has been elected; the losses have been—defaulters, 4, resignations, 7, and death, 1. The number on the roll on the 1st instant was therefore 146.

Mr. Richard Johnson, F.C.S., the deceased member, was born in Manchester in the year 1809, and came of an old Lancashire family. At a comparatively early age he joined his father and one of his brothers in business, as wire and pin manufacturers, and under his and his brother Mr. Wm. Johnson's active and enterprising management, the business grew, and soon attained a world-wide celebrity for the manufacture of telegraph and rope wire.

Upwards of thirty years ago Mr. Johnson was elected a fellow of this Society, and, aided by the late Dr. Crace-Calvert, commenced a series of careful experiments on alloys of zinc, tin, and copper in definite proportions. The results of these experiments were published in the British Association Report for 1855. Mr. Johnson continued to experiment on this subject for several years, making some of the first experiments on the expansion of alloys by heat, their heat conductivity, and specific gravity, see Phil. Mag., XIV., 1857, XVIII., 1859, etc. Shortly after he invented a machine for testing the hardness of alloys and metals generally, and made many useful experiments.

Perhaps, however, his most important investigations were on the chemical changes which pig iron undergoes during its conversion into wrought iron. For more than one hundred years previously pig iron had been converted into wrought iron by puddling; but it was reserved for Mr. Johnson to explain the nature of the change, by the careful analyses he made of samples of the iron, taken at short intervals, during the process of puddling.

These experiments are described in detail in the Phil. Mag., XIV., 1857.

Mr. Johnson was always very active in the cause of education. He took a deep interest both in Owens College and the Manchester Grammar School. To the end of his life he remained a careful and constant reader; by degrees he surrounded himself with a large and valuable library and picture gallery. He died on the 16th of February last, at his residence, Kemnal Manor, Chislehurst, after a short illness, much regretted by all who knew him.

Various proposals for the celebration of the Centenary of the Society have been carefully considered by the Council, but in the present state of the Society's finances the Council do not feel justified in recommending for adoption any scheme involving certain, and probably considerable, expense, but which would be of very doubtful utility to the Society.

At the request of the Committee appointed at the last annual meeting, Dr. R. Angus Smith, F.R.S., has kindly drawn up a report on the work of the Society since its foundation, an abstract of which will be read at the annual meeting.

The following papers and communications have been read at the Ordinary and Sectional Meetings of the Society during the Session:—

October 5th, 1880.—"Colorimetry, Part VI.," by James Bottomley, B.A., D.Sc.

"The Antiquity of Toughened Glass," by William E. A. Axon, M.R.S.L., F.S.S.

October 11th, 1880.—"On Some Entomostracæ, &c., found in Derwentwater in September, 1879," by Mr. John Boyd.

October 19th, 1880.—"On the Word Chemia," by Dr. R. Angus Smith, F.R.S.

"Additional Notes on a Theory of Mixed Opaque Colours," by James Bottomley, D.Sc.

"On Some Early Anticipations of Heliographic Signalling," by William E. A. Axon, M.R.S.L.

"On Some Marine Fossil Shells in the Middle Coal Measures of Lancashire," by E. W. Binney, F.R.S., F.G.S., President.

"Some Endeavours to Ascertain the Nature of the Insoluble Form of Soda Existing in the Residue left on Causticising Sodium Carbonate with Lime," by Watson Smith, F.C.S., Assistant Lecturer on Chemistry in the Owens College, and Mr. W. T. Liddle.

November 2nd, 1880.—"On the Conditions of the Motion of a Portion of Fluid in the Manner of a Rigid Body," by R. F. Gwyther, M.A.

"Did Pascal Invent the Wheelbarrow?" by William E. A. Axon, M.R.S.L.

"On the History of the Artificial Preparation of Indigo," by Carl Schorlemmer, F.R.S.

"Some Further Experiments on the Cohesion of Water and Mercury," by Professor Osborne Reynolds, F.R.S.

November 9th, 1880.—"On Gravitation," by the Rev. Thomas Mackereth, F.R.A.S., F.M.S.

November 16th, 1880.—"Note on the Presence of Sulphur in Illuminating Gas," by Harry Grimshaw, F.C.S.

December 14th, 1880.—"Boulder Stones as Grave Stones," by E. W. Binney, F.R.S., F.G.S., President.

"The Land Subsidence at Northwich," by Thomas Ward, Esq.

"Some Endeavours to Ascertain the Nature of the Insoluble Form of Soda existing in the Residue left on Causticising Sodium Carbonate Solutions with Lime, Part II.," by Watson Smith, F.C.S., Assistant Lecturer on Chemistry in the Owens College, and Mr. W. T. Liddle. Communicated by Professor C. Schorlemmer, F.R.S.

December 28th, 1880.—"The Literary History of Parnell's Hermit," by William E. A. Axon, M.R.S.L.

January 25th, 1881.—"On the Question of the Desirability of the Society's Library being handed over to the Reference Library of the Corporation," by R. D. Darbishire, F.G.S.

February 14th, 1881.—"On Pendant Nests of a Gregarious Moth from Venezuela," by John Plant, F.G.S.

February 22nd, 1881.—"List of Severe Winters and Famines," by Mr. Herman Hager. Communicated by Professor Balfour Stewart, F.R.S.

"Ozone and the Rate of Mortality at Southport during the Nine Years, 1872-1880," by Joseph Baxendell, F.R.A.S.

"On Some Objects of Ancient Date found in Digging Foundations for New Buildings on Land lying between Hanging Bridge and Cateaton-street, Manchester," by E. W. Binney, F.R.S., F.G.S., President.

"On the Addition and Multiplication of Logical Relatives," by Joseph John Murphy, F.G.S. Communicated by the Rev. Robert Harley, F.R.S.

March 8th, 1881.—"Additions to the Paper 'On an Adaptation of the Lagrangian Form of the Equations of Fluid Motion,'" by R. F. Gwyther, M.A.

"A Sulphuretted Hydrogen Apparatus," by Peter Hart, Esq.

"Note on an Attempt to Analyse the Recorded Diurnal Ranges of Magnetic Declination," by Balfour Stewart, M.A., LL.D., F.R.S., Professor of Natural Philosophy at the Owens College, and Wm. Dodgson, Esq.

March 14th, 1881.—"On Some Curious Forms of Fresh-Water Mollusca from Lake Tanganyika, Central Africa," by James Cosmo Melvill, F.L.S.

March 22nd, 1881.—"On the Growth and Use of a Symbolical Language," by M. Hugh Mc.Coll, B.A. Communicated by the Rev. Robert Harley, M.A., F.R.S.

Four Letters of the late Mr. Thomas Carlyle, addressed by him to the late Mr. Samuel Bamford, of Blackley, the author of "Passages in the Life of a Radical." Communicated by E. W. Binney, F.R.S., F.G.S., President.

March 29th, 1881.—"On the Motion of Developable Cylinders," by James Bottomley, D.Sc., F.C.S.

April 5th, 1881.—"On Du Bourguet's 'Calcul' and on Ternaries," by Sir James Cockle, F.R.S., Corresponding Member of the Society.

"On a Eucalyptus Globulous at Douglas, Isle of Man," by E. W. Binney, F.R.S., F.G.S., President.

"Note on the Presence of Arsenic in Paper Hangings," by Harry Grimshaw, F.C.S.

"On the Action of Sulphuric Acid from Gas Lights on a Zinc Plate," by J. P. Joule, D.C.L., LL.D., F.R.S., &c.

"On the Relation between the Electrical Resistance and Chemical Constitution of Steel Wire," by William H. Johnson, B.Sc.

Several of these papers have already been printed, and others passed by the Council for printing in the new Volume of Memoirs.

The Council still consider it desirable to continue the system of electing Sectional Associates, and a resolution on the subject will be submitted to the Annual Meeting for the approval of the Members.

The Librarian reports that the number of societies with which we correspond is nearly the same as last year, and that Vol. VI., 3rd Series, of our Memoirs, and Vols. 16 to 19 of the Proceedings, have been forwarded to these societies and to all our honorary and corresponding members. In the case of the societies the volumes were accompanied with requests to fill up vacancies where required, and in reply we have received many volumes to complete our sets.

Dr. CHARLES BAILEY, TREASURER, IN ACCOUNT WITH THE SOCIETY,
STATEMENT OF THE ACCOUNTS

	£	s.	d.	1880-1. £	s.	d.	1879-80. £	s.	d.
1880.—April 1.									
To Cash in hand				124	10	3	8	10	[illegible]
1881.—March 31.									
To Members' Contributions :—									
Arrears, 1877-8, 1 at £2 2s.	2	2	0						
,, 1878-9, 1 at £2 2s.	2	2	0						
,, 1879-80, 10 at £2 2s.	21	0	0						
New Members' Admission Fees, 1880-1, 1 at £2 2s.	2	2	0						
,, Subscriptions, 1880-1, 1 at £2 2s.	2	2	0						
Old Members' ,, ,, 130 at £2 2s.	273	0	0						
				302	8	0	343	7	[illegible]
To one Associate's Subscription for Library, 1880-1	0	10	0						
To Sectional Contributions :—									
Physical and Mathematical Section, 1880-1	2	2	0						
Microscopical and Natural History Section, 1879-81	4	4	0						
				6	16	0	2	12	[illegible]
To use of Society's Rooms :—									
Manchester Geological Society, to 31st March, 1880	30	0	0						
Manchester Scientific Students' Association (1 meeting)	1	5	0						
Manchester Medical Society (1 meeting)	1	15	0						
				33	0	0	66	5	[illegible]
To Sale of Society's Publications				10	19	7	1	18	[illegible]
To Natural History Fund :—									
Dividends on £1225 Gt. Western Stock				59	15	3	59	19	[illegible]
To Bank Interest, less Bank Postage, to 31st December, 1880				1	18	4	0	14	7
				£539	7	5	£483	6	1

1881.—April 1. To Cash in Manchester and Salford Bank £111 5 1

11th April, 1881.

Audited and found correct,
(Signed) T. CLEMENT TRAPP.
WILLIAM H. JOHNSON.

PHILOSOPHICAL SOCIETY.

FROM 1ST APRIL, 1880, TO THE 31ST MARCH, 1881, WITH A COMPARATIVE FOR THE SESSION 1879-1880.

Cr.

1881—March 31.	1880-1. £ s. d.	£ s. d.	1879-80. £ s. d.	£ s. d.
By Charges on Property :—				
Chief Rent	12 12 0		12 13 0	
Insurance against Fire	12 17 6		12 17 6	
Property Tax	4 5 0		3 10 10	
Repairs, Whitewashing, &c.	2 16 10		0 18 2	
		32 11 4		29 19 6
By House Expenditure :—				
Coals, Gas, Candles, and Water	17 19 7		12 16 1	
Tea and Coffee at Meetings	16 6 1		19 4 3	
House Duty	6 7 6		6 7 6	
Cleaning, Brushes, Sundries	5 11 2		5 5 8	
		46 4 4		43 13 6
By Administrative Charges :—				
Wages of Keeper of Rooms	57 4 0		57 4 0	
Postages and Carriage of Parcels	24 5 6		17 4 0	
Attendance on Sections and Societies	9 9 0		11 19 0	
Stationery and Printing Circulars	11 16 6		10 4 1	
		102 15 0		96 11 1
By Publishing :—				
Printing Memoirs	42 16 0		30 1 6	
Printing Proceedings	41 4 0		47 17 0	
Wood Engraving and Lithographing	8 5 0		4 13 0	
Editor of Memoirs and Proceedings	50 0 0		50 0 0	
		142 5 0		132 11 6
By Library :—				
Binding Transactions	8 17 4		— — —	
Binding Books for Library	16 16 11		2 18 3	
Books and Periodicals	16 0 5		38 19 6	
Assistant in Library	20 10 0		11 10 0	
Geological Record for 1877	— — —		0 10 6	
Palæontographical Society for 1881	1 1 0		1 1 0	
Ray Society for 1881	1 1 0		1 1 0	
		64 6 8		56 0 3
By Natural History Fund :—				
Grant to Section for Books		40 0 0		— — —
By Balance		111 5 1		124 10 3
		£539 7 5		£483 6 1

	1880-1. £ s. d.	£ s. d.
Compounders' Fund :—		
Balance in favour of this Account, April 1st, 1881		125 0 0
Natural History Fund :—		
Balance in favour of this Account, April 1st, 1880	56 10 5	
Dividends as above	59 15 3	
	116 5 8	
Less Grant for Natural History Works	40 0 0	
Balance in favour of this Account, April 1st, 1881		76 5 8
		£201 5 8
General Fund :—		
Balance against this Account, April 1st, 1880	57 0 2	
Expenditure, 1880–1, as above	388 2 4	
	445 2 6	
Receipts, 1880–1, as above	355 1 11	
Balance against this Account, April 1st, 1881		90 0 7
Balance in favour of the Society, April 1st, 1881		£111 5 1

Dr. CHARLES BAILEY, TREASURER, IN ACCOUNT WITH THE SOCIETY, FROM 1ST APRIL, 1880, TO THE 31ST MARCH, 1881, WITH A COMPARATIVE STATEMENT OF THE ACCOUNTS FOR THE SESSION 1879-1880. **Cr.**

	1880-1. £ s. d.	1880-1. £ s. d.	1879-80. £ s. d.
1880.—April 1.			
To Cash in hand		124 10 3	8 10 [illegible]
1881.—March 31.			
To Members' Contributions:—			
Arrears, 1877-8, 1 at £2 2s.	2 2 0		
,, 1878-9, 1 at £2 2s.	2 2 0		
,, 1879-80, 10 at £2 2s.	21 0 0		
New Members' Admission Fees, 1880-1, 1 at £2 2s.	2 2 0		
,, Subscriptions, 1880-1, 1 at £2 2s.	2 2 0		
Old Members' ,, ,, 130 at £2 2s.	273 0 0		
		302 8 0	343 7 [illegible]
To one Associate's Subscription for Library, 1880-1	0 10 0		
To Sectional Contributions:—			
Physical and Mathematical Section, 1880-1	2 2 0		
Microscopical and Natural History Section, 1879-81	4 4 0		
		6 16 0	2 12 [illegible]
To use of Society's Rooms:—			
Manchester Geological Society, to 31st March, 1880	30 0 0		
Manchester Scientific Students' Association (1 meeting)	1 5 0		
Manchester Medical Society (1 meeting)	1 15 0		
		33 0 0	66 5 [illegible]
To Sale of Society's Publications		10 19 7	1 18 [illegible]
To Natural History Fund:—			
Dividends on £1225 Gt. Western Stock		59 15 3	59 19 [illegible]
To Bank Interest, less Bank Postage, to 31st December, 1880		1 18 4	0 14 7
		£539 7 5	£483 6 1

1881.—April 1. To Cash in Manchester and Salford Bank £111 5 1

11th April, 1881.

Audited and found correct,

(Signed) T. CLEMENT TRAPP.
WILLIAM H. JOHNSON.

	1880-1. £ s. d.	1880-1. £ s. d.	1879-80. £ s. d.	1879-80. £ s. d.
1881—March 31.				
By Charges on Property:—				
Chief Rent	12 12 0		12 13 0	
Insurance against Fire	12 17 6		12 17 6	
Property Tax	4 5 0		3 10 10	
Repairs, Whitewashing, &c.	2 16 10		0 18 2	
		32 11 4		29 19 6
By House Expenditure:—				
Coals, Gas, Candles, and Water	17 19 7		12 16 1	
Tea and Coffee at Meetings	16 6 1		19 4 3	
House Duty	6 7 6		6 7 6	
Cleaning, Brushes, Sundries	5 11 2		5 5 8	
		46 4 4		43 13 0
By Administrative Charges:—				
Wages of Keeper of Rooms	57 4 0		57 4 0	
Postages and Carriage of Parcels	24 5 0		17 4 0	
Attendance on Sections and Societies	9 9 0		11 19 0	
Stationery and Printing Circulars	11 16 6		10 4 1	
		102 15 0		96 11 1
By Publishing:—				
Printing Memoirs	42 16 0		30 1 0	
Printing Proceedings	41 4 0		47 17 0	
Wood Engraving and Lithographing	8 5 0		4 13 0	
Editor of Memoirs and Proceedings	50 0 0		50 0 0	
		142 5 0		132 11 6
By Library:—				
Binding Transactions	8 17 4		— — —	
Binding Books for Library	16 16 11		2 18 3	
Books and Periodicals	16 0 5		38 19 0	
Assistant in Library	20 10 0		11 10 0	
Geological Record for 1877	— — —		0 10 6	
Palæontographical Society for 1881	1 1 0		1 1 0	
Ray Society for 1881	1 1 0		1 1 0	
		64 6 8		56 0 3
By Natural History Fund:—				
Grant to Section for Books		40 0 0		— — —
By Balance		111 5 1		124 10 3
		£539 7 5		£483 6 1

	1880-1. £ s. d.	1880-1. £ s. d.
Compounders' Fund:—		
Balance in favour of this Account, April 1st, 1881		125 0 0
Natural History Fund:—		
Balance in favour of this Account, April 1st, 1880	56 10 5	
Dividends as above	59 15 3	
	116 5 8	
Less Grant for Natural History Works	40 0 0	
Balance in favour of this Account, April 1st, 1881		76 5 8
		£201 5 8
General Fund:—		
Balance against this Account, April 1st, 1880	57 0 2	
Expenditure, 1880-1, as above	388 2 4	
	445 2 6	
Receipts, 1880-1, as above	355 1 11	
Balance against this Account, April 1st, 1881		90 0 7
Balance in favour of the Society, April 1st, 1881		£111 5 1

On the motion of Mr. A. Brothers, seconded by Mr. R. S. Dale, the Report was unanimously adopted and ordered to be printed in the Society's Proceedings.

On the motion of Mr. J. Smith, seconded by Mr. H. Grimshaw, it was resolved unanimously: That the system of electing Sectional Associates be continued during the ensuing Session.

The following gentlemen were elected Officers of the Society and Members of the Council for the ensuing year:—

President.

EDWARD WILLIAM BINNEY, F.R.S., F.G.S.

Vice-Presidents.

JAMES PRESCOTT JOULE, D.C.L., LL.D., F.R.S., F.C.S.
EDWARD SCHUNCK, Ph.D., F.R.S., F.C.S.
ROBERT ANGUS SMITH, Ph.D., F.R.S., F.C.S.
HENRY ENFIELD ROSCOE, B.A., Ph.D., F.R.S., F.C.S.

Secretaries.

JOSEPH BAXENDELL, F.R.A.S.
OSBORNE REYNOLDS, M.A., F.R.S.

Treasurer.

CHARLES BAILEY, F.L.S.

Librarian.

FRANCIS NICHOLSON, F.Z.S.

Other Members of the Council.

REV. WILLIAM GASKELL, M.A.
ROBERT DUKINFIELD DARBISHIRE, B.A., F.G.S.
BALFOUR STEWART, LL.D., F.R.S.
CARL SCHORLEMMER, F.R.S.
JAMES BOTTOMLEY, B.A., D.Sc., F.C.S.
WILLIAM HENRY JOHNSON, B.Sc.

Dr. R. Angus Smith, F.R.S., read an abstract of his report on the work of the Society since its foundation.

On the motion of Mr. C. Bailey, seconded by Mr. R. D. Darbishire, the thanks of the Society were unanimously voted to Dr. Smith for his report.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

Annual Meeting, April 11th, 1881.

E. W. Binney, F.R.S., F.G.S., in the Chair.

The Annual Report was read by the Secretary, and the Treasurer presented his Annual Statement of the financial position of the Section, both of which were confirmed and passed.

The following were elected officers for the ensuing year, 1881-1882:—

President:

A. BROTHERS, F.R.A.S.

Vice-Presidents:

CHARLES BAILEY, F.L.S.
E. W. BINNEY, F.R.S., F.G.S.
R. D. DARBISHIRE, F.G.S.

Treasurer:

T. H. BIRLEY (Somerville).

Secretaries:

J. COSMO MELVILL, M.A., F.L.S.
ROBERT E. CUNLIFFE.

Council:

W. C. WILLIAMSON, F.R.S.
W. BOYD DAWKINS, F.R S., F.G.S.
J. BOYD.
A. MILNES MARSHALL.
Dr. ALCOCK.
HASTINGS C. DENT.
S. MOORE.
W. E. BARRATT.

Professor BOYD DAWKINS, F.R.S., made some remarks with reference to the dates of the introduction of the Pheasant and Fallow Deer into England. He stated that there were entries of the Monks of Waltham, of allowances to the Canons, from which it would appear that the pheasant was known as early as A.D. 1050; and from remains found in Roman refuse heaps it was probable that the fallow deer was introduced during the period of the Roman occupation of Britain.

Mr. THOS. ROGERS exhibited specimens of Erinus Alpinus from Downham, near Clitheroe, where the plant is found in considerable profusion, especially on the wall of the vicarage garden, and made some remarks on the probable naturalization of the plant in England.

The following paper was received after the Annual General Meeting, April 19th, 1881 :—

"First Resolvents of the Quartic

$$y^4 + ay^2 + x_1 y - \frac{a^2}{12} = 0 \quad \ldots\ldots\ldots\ldots \quad (1)$$

and the Cubic

$$ay^3 + 3by^2 + 3cy + m = 0 \quad \ldots\ldots\ldots\ldots \quad (2)"$$

By ROBERT RAWSON, Esq., Hon. Memb. M. L. & Phil. Soc., Assoc. I.N.A., Mem. of the Lon. Math. Society.

1. Differentiate (1) with respect to x, x_1 being a function of x and (a) being a constant.

$$\therefore \; (4y^4 + 2ay^2 + x_1 y)\frac{dy}{dx} + \frac{dx_1}{dx}y^2 = 0 \quad \ldots\ldots\ldots\ldots (3)$$

Eliminate y^4 in (3) by means of (1)

$$\text{Then,} \; (6ay^2 + 9x_1 y - a^2)\frac{dy}{dx} = 3y^2\frac{dx_1}{dx} \quad \ldots\ldots\ldots\ldots (4)$$

$$\text{Put,} \; (6ay^2 + 9x_1 y - a^2)(ly^2 + my + n) = 3y^2\frac{dx_1}{dx} \quad \ldots\ldots\ldots (5)$$

Equation (5) is satisfied by

$$(8a^3 + 27x_1^2)l + 6a\frac{dx_1}{dx} = 0$$

$$(8a^3+27x_1^2)m-9x_1\frac{dx_1}{dx}=0$$

$$(8a^3+27x_1^2)n+3a^2\frac{dx_1}{dx}=0$$

Substitute the above values of l, m, n in

$$\frac{dy}{dx}=ly^2+my+n$$

Then $$(8a^3+27x_1^2)\frac{dy}{dx}+3\frac{dx_1}{dx}(2ay^2-3x_1y+a^2)=0 \text{ ....(6)}$$

An equation, which is called the first Resolvent of the quartic (1).

Each of the roots of this quartic is, therefore, a particular solution of (6), and any value of y which satisfies (6) is, therefore, a root of the quartic (1).

2. A general solution of (6) is obtained as follows :—

Let $y=y_1+v$ be a general solution ....(7) where y_1 is one of the roots of the quartic (1), and, v a new variable to be determined.

Substitute the above value of y in (6) and it becomes

$$(8a^3+27x_1^2)\left(\frac{dy_1}{dx}+\frac{dv}{dx}\right)+3\frac{dx_1}{dx}\left\{2a(y_1+v)^2-3x_1(y_1+v)+a^2\right\}=0$$

From which is derived

$$(8a^3+27x_1^2)\frac{dv}{dx}+3\frac{dx_1}{dx}\left\{2av^2+(4ay_1-3x_1)v\right\}=\quad 0\text{......(8)}$$

This equation is a well known integrable form, and, by integrating it in the usual way, putting $(8a^3+27x_1^2)\mathrm{P}=6a\frac{dx_1}{dx}$ then we obtain

$$v\left(c+\int\left\{\mathrm{P}\exp.\int\left(\frac{3x_1}{2a}-2y_1\right)\mathrm{P}dx\right\}\right)=\exp.\int\left(\frac{3x_1}{2a}-2y_1\right)\mathrm{P}dx\text{...(9)}$$

using the convenient notation of Professor Cayley, viz., $\epsilon^z=\exp.z$.

Hence the general integral, or complete primitive of (6) is

$$y=y_1+\frac{\exp.\int\left(\frac{3x_1}{2a}-2y_1\right)\mathrm{P}dx}{c+\int\left\{\mathrm{P}\exp.\int\left(\frac{3x_1}{2a}-2y_1\right)\mathrm{P}dx\right\}dx}\text{ ...... (10)}$$

3. Equation (6) is made linear of the second order by the assumption of

$$y = \frac{8a^3 + 27x_1^2}{6a\frac{dx_1}{dx}} \cdot \frac{du}{udx} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Substitute the above value of y in (6) and we obtain

$$\frac{d^2u}{dx^2} + \left\{ \frac{45x_1\frac{dx_1}{dx}}{8a^3 + 27x_1^2} - \frac{\frac{d^2x_1}{dx^2}}{\frac{dx_1}{dx}} \right\} \frac{du}{dx} + 18a^3 \left(\frac{\frac{dx_1}{dx}}{8a^3 + 27x_1^2} \right)^2 u = 0 \ldots\ldots (12)$$

The general integral of (12) is, therefore, the value of (u) determined from (11) wherein y takes the value given in equation (10).

4. The following particular case is of some interest in the theory of elliptic functions.

Put, $x_1 = -4\left(x + \frac{1}{x}\right)$, and $a = 6$.

Substitute these values in equations (1) and (6); then they become as follows:

$$y^4 - 6y^2 - 4\left(x + \frac{1}{x}\right)y - 3 = 0 \ldots\ldots\ldots\ldots\ldots (13)$$

$$3(1 - x^2)\frac{dy}{dx} - y^2 + \left(x + \frac{1}{x}\right)y + 3 = 0 \ldots\ldots\ldots\ldots (14)$$

The various steps in the substitution and reduction, being simple, are omitted.

Equation (14) has been considered by Professor Cayley in the *Messenger of Mathematics*, Vol. IV., pages 69, 110, and *Elliptic Functions*, page 248; and also by Mr. Hart, in the *Messenger of Mathematics*, Vol. IV., page 125.

The general solution of (14) is given by the substitution of $x_1 = -4\left(x + \frac{1}{x}\right)$, and, $a = 6$ in equation (10) and is as follows:

$$y = y_1 + \frac{\left(\frac{x^2 - 1}{x}\right)^{\frac{1}{3}} \exp. \frac{2}{3}\int \frac{y_1 dx}{1 - x^2}}{c + \frac{1}{3}\int \left\{ \left(\frac{1}{(x^2 - 1)^2 x}\right)^{\frac{1}{3}} \exp. \frac{2}{3}\int \frac{1 - x^2}{y_1 dx} \right\} dx} \ldots\ldots\ldots (15)$$

5. Professor Cayley states correctly that a particular solution of (14) is given by

$$y = v^2x^{-\frac{1}{2}} + 2vx^{\frac{1}{4}} = v^{-2}x^{\frac{1}{2}} + 2v^{-1}x^{-\frac{1}{4}} \ldots\ldots\ldots\ldots\ldots (16)$$

where, v is a root of the quartic

$$v^4 + 2x^{\frac{3}{4}}v^3 - 2x^{\frac{1}{4}}v - x = 0 \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

And, to obtain a general solution, he transforms (14) into a differential equation of the second order, from which a general solution is derived in the usual way. Such transformation is obviated by the procedure of Art. 2. Of course the elimination of v between (16) and (17) will give (13) as follows:

$$y^2 = (v^2x^{-\frac{1}{2}} + 2vx^{\frac{1}{4}})(v^{-2}x^{\frac{1}{2}} + 2v^{-1}x^{-\frac{1}{4}})$$

$$= 2v^{-1}x^{\frac{3}{4}} + 2vx^{-\frac{3}{4}} + 5$$

$$\therefore y^2 - 6 = 2v^{-1}x^{\frac{3}{4}} + 2vx^{-\frac{3}{4}} - 1$$

and,

$$y^4 - 6y^2 = 4v^{-2}x_2^3 + 8v^{-1}x^{\frac{3}{4}} + 4v^2x^{-\frac{3}{4}} + 8vx^{-\frac{3}{4}} + 3$$

$$-4\left(x + \frac{1}{x}\right)y = -4x^{-2}x^{\frac{3}{2}} - 8v^{-1}x^{\frac{3}{4}} - 4v^2x^{-\frac{3}{4}} - 8vx^{-\frac{3}{4}}$$

$$\text{Then, } y^4 - 6y^2 - 4\left(x + \frac{1}{x}\right)y - 3 = 0$$

which agrees with (13) as it should do.

6. A root of (13) may be found by changing the independent variable x to another independent variable z connected with the former by a given relation. This has been done by Professor Cayley in a particular case (see *Messenger of Mathematics*, page 111.) Put $y = \phi(z)$

$$\therefore x + \frac{1}{x} = \frac{\phi(z)^2\{\phi(z)^2 - 6\} - 3}{4\phi(z)}$$

$$\text{If } \phi(z)^2 = \frac{2z^2 + 5z + 2}{z}$$

$$\therefore x + \frac{1}{x} = \frac{z^4 + 2z^2 + 2z + 1}{z\sqrt{z}\sqrt{2z^2 + 5z + 2}}$$

$$\text{From which, } x^2 = \frac{z^3(2 + z)}{1 + 2z}$$

which agrees with Professor Cayley's results.

The advantage of this transformation is questionable, as particular values of x only can be obtained by it, except by the solution of the quartic

$$z^4 + 2z^3 - 2x^2z - x^2 = 0.$$

The selection, as it appears to me, must lie between the above quartic and the quartic (13).

7. Differentiate (2) with respect to x, where a, b, c, m are functions of x, and put as usual $\frac{dy}{dx} = y^1$, &c.

$$\therefore\ y^1 + \frac{a^1y^3 + 3b^1y^2 + 3c^1y + m^1}{3ay^2 + 6by + 3c} = 0$$

Eliminate y^3 by means of (2)

$$\therefore\ y^1 + \frac{(ab^1 - ba^1)y^2 + (ac^1 - ca^1)y + \frac{1}{3}(am^1 - ma^1)}{a^2y^2 + 2aby + ac} = 0 \quad \ldots\ldots(18)$$

Put $(ab^1 - ba^1)y^2 + (ac^1 - ca^1)y + \frac{1}{3}(am^1 - ma^1)$

$$= (a^2y^2 + 2aby + ac)(\mathrm{P}y^2 + \mathrm{Q}y + \mathrm{R}) \quad \ldots\ldots\ldots\ldots\ldots(19)$$

Then (18) becomes

$$y^1 + \mathrm{P}y^2 + \mathrm{Q}y + \mathrm{R} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(20)$$

which is the first resolvent of the cubic (2).

Multiplying the right-hand side of (19), and, eliminate y^4, y^3 by means of (2), there results

$$(3b^2 - 2ac)\mathrm{P} - ab\mathrm{Q} + a^2\mathrm{R} = ab^1 - ba^1$$
$$(3bc - am)\mathrm{P} - 2ac\mathrm{Q} + 2ab\mathrm{R} = ac^1 - ca^1$$
$$bm\mathrm{P} - am\mathrm{Q} + ac\mathrm{R} = \frac{1}{3}(am^1 - ma^1) \quad \ldots\ldots\ldots\ldots\ldots(21)$$

The values, therefore, of P, Q, R, which satisfies equation (20) are to be determined from the system (21), and are as follows :—

Put $\alpha = 3(3b^2c^2 - 4ac^3 - 4b^3m + 6abcm - a^2m^2) \quad \ldots\ldots(22)$

$$\begin{aligned}\therefore\ \alpha\mathrm{P} = {} & (4b^2m - 3bc^2 - acm)a^1 \\ & + 6a(c^2 - bm)b^1 \\ & + 3a(am - bc)c^1 \\ & + 2a(b^2 - ac)m^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (23)\end{aligned}$$

$$\begin{aligned}\alpha\mathrm{Q} = {} & (7bcm - 6c^3 - am^2)a^1 \\ & + 3(3bc^2 - 2b^2m - acm)b^1 \\ & + 3(2ac^2 + abm - 3b^2c)c^1 \\ & + (6b^3 + a^2m - 7abc)m^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots(24)\end{aligned}$$

$$\begin{aligned}\alpha\mathrm{R} = {} & 2m(bm - c^2)a^1 \\ & + 3m(bc - am)b^1 \\ & + 6m(ac - b^2)c^1 \\ & + (3b^2c + abm - 4ac^2)m^1 \quad \ldots\ldots\ldots\ldots\ldots\ldots(25)\end{aligned}$$

Each of the three roots of (2) is a particular solution of (20), and a solution of (20) is, therefore, a root of (2).

The above values of P, Q, R, agree with the results of Wm. Spottiswoode, M.A., F.R.S. (See Manchester P. Society's Memoirs, Vol. II., third series, page 230.)

The reader of Mr. Spottiswoode's paper above referred to must make the following corrections, viz., page 231, for $(a^1)^2a^2b$ read $(a^1)^2a^2d$ in line 10 from top; in line 11 from top, for $3a^1b^1ad^2$ read $a^1b^1(3ad^2-9bcd)$. Mr. Spottiswoode has pointed out the line to be pursued to obtain the resolvent of the second order. (See also Rev. Robert Harley's Report on the Theory of Differential Resolvents to the British Association for the Advancement of Science, 1873.

The problem, viz: to find the second differential resolvent of a general cubic is exceedingly complex and tedious; it was completely solved by me some three or four years ago and the results sent to the Rev. Robert Harley, F.R.S., &c., in whose possession they still remain.

8. The equation (20) is soluble when c, m are constants, and $am^2=3bcm-2c^3$. Hence, the root of the following cubic is obtained by integration, viz:

$$(3bcm-2c^3)y^3+3bm^2y^2+3cm^2y+m^3=0.$$

9. When $b=0$ then, $\alpha=-3a(4c^3+am^2)$

$$\text{and, } \alpha P=-acma^1+3a^2mc^1-2a^2cm^1 \quad\ldots\ldots(26)$$

$$\text{and, } \alpha Q=-(6c^3+am^2)a^1+6ac^2c^1+a^2mm^1 \quad\ldots\ldots(27)$$

$$\text{and, } \alpha R=-2c^2ma^1+6acmc^1-4ac^2m^1 \quad\ldots\ldots(28)$$

The further condition, $c^3=c_1am^2$, where c_1 is an arbitrary constant, will cause P, R, to vanish, thereby rendering equation (20) soluble, and determine by integration a root of the cubic

$$c^3y^3+3c_1cm^2y+c_1m^3=0 \quad\ldots\ldots(29)$$

10. With a view of obtaining a root of a general cubic by integration it will be necessary to examine the conditions of solubility of equation (20) which are given by Abel. (See Abel's works, vol. 2).

The following may be of some use in the pursuance of this object.

Let, $(y+a)^n(y+b)^m = p\epsilon^{\int c dx}$ ....(30)

where a, b, c are functions of x, and p constant.

By taking the log. of (30) it is readily shown that

$$y^1 + \frac{-cy^2 + \{na^1 + mb^1 - c(a+b)\}y + nba^1 + mab^1 - abc}{(n+m)y + ma + nb} \ldots (31)$$

If $m = -n$, then, $(y+a)^n = p(y+b)^n \epsilon^{\int c dx}$ is a particular integral of

$$y^1 + \frac{cy^2}{n(a-b)} + \left\{\frac{c(a+b)}{n(a-b)} - \frac{a^1 - b^1}{a-b}\right\}y + \frac{abc}{n(a-b)} - \frac{ba^1 - ab^1}{a-b} = 0 \ldots (32)$$

PROCEEDINGS

OF THE

MANCHESTER

LITERARY AND PHILOSOPHICAL SOCIETY.

VOL. XXI.

SESSION 1881–82.

MANCHESTER:
PRINTED BY T. SOWLER AND CO., 24, CANNON STREET.
LONDON: BALLIÈRE, 219, REGENT STREET.
1882.

NOTE.

The object which the Society have in view in publishing their Proceedings is to give an immediate and succinct account of the scientific and other business transacted at their meetings to the members and the general public. The various communications are supplied by the authors themselves, who are alone responsible for the facts and reasonings contained therein.

INDEX.

PROCEEDINGS

OF THE

MANCHESTER

LITERARY AND PHILOSOPHICAL SOCIETY.

Ordinary Meeting, October 4th, 1881.

J. P. JOULE, D.C.L., LL.D., F.R.S., &c., in the Chair.

"On Drops Floating on the Surface of Water," by Professor OSBORNE REYNOLDS, F.R.S.

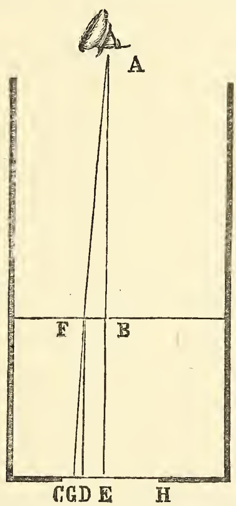
It is well known that under certain circumstances drops of water may be seen floating on the surface for some seconds before they disappear. Sometimes during a shower of rain these drops are seen on the surface of a pond, they are also often seen at the bows of a boat when travelling sufficiently fast to throw up a spray. Attempts have been made to explain this phenomenon, but I am not aware of any experiments to determine the circumstances under which these drops are suspended. Having been deeply engaged in the experimental study of the phenomena of the surface tension of water and the effect of the scum formed by oil or other substances, it occurred to me that the comparative rarity of these floating drops would be explained if it could be shown that they required a pure surface, a surface free from scum of any kind. For, owing to the high surface tension of pure water, its surface is rarely free from scum. The surface of stagnant water is practically never free except when the scum is driven off by wind. But almost any disturbance in the water, such as the motion of the point of a stick round and round in the water, or water splashed on the surface, will serve to drive back the scum for a certain distance. This may be shown by scattering some flowers of sulphur on the surface. This powder is insoluble and produces no scum, and hence it serves admirably to show the motion of the surface and whatever scum there may be upon it. If when the surface is so dusted a splash be made by a stick so as to throw drops on to the sulphured surface, at the first splash no floating drops are produced; but after two or three splashes in rapid succession it will be seen that the sulphured scum has been driven back by the falling water, leaving a patch of clear surface, and on this drops will float in large numbers and of all sizes. These drops are entirely confined to that portion of the surface which is clear. The drops, either by their initial motion or by the current of air, glide rapidly over the surface from the point at which they are formed. When, however, they reach the edge of the scum they disappear, apparently somewhat gradually. I have this summer made the experiment on several ponds and on various days, and I have never found any difference. Any scum, however transparent, prevented the drops, and they always floated in large numbers when the scum was driven back in the manner described, by the wind or any other way.

This result points to the conclusion that whatever may be the cause of this suspension, it depends only on the surface of the water being pure, and not at all on the temperature or condition of the air.

"On the Mean Intensity of Light that has passed through Absorbing Media," by JAMES BOTTOMLEY, D.Sc., F.C.S.

In colorimetric experiments the areas compared are assumed to be of the same tint throughout. When, however, we look through columns of coloured liquid at external white surfaces, this condition will not be exactly fulfilled.

Suppose the bottom of the containing cylinder to be perfectly flat. Owing to the adhesion of the liquid to the sides, and the consequent elevation there above the general level, the colour will be more intense near the sides. This, however, if the cylinders are of moderate radius, may be remedied by covering the bottom with a black plate having a small aperture in the centre; in this way the rays coming from the sides are cut off. But, even supposing this done, the colour will not be exactly the same over the whole area. Suppose an eye to be placed at A in the axis of the



cylinder, and let CH represent the section by a vertical plane of the circular area at the bottom admitting light. Let AE be the ray which passes through the centre; the path of this ray through the liquid will be EB. Let AFG be another ray which reaches the eye; the path of this ray through the liquid is FG; and as this is greater than EB, the absorption will be greater. Hence the colour will gradually increase in intensity as we pass from the centre to the circumference. For colorimetric measurements we take the vertical length of the column of liquid. In what follows I propose to consider if this would lead to any noticeable error. Our impression of colour will not be derived from a consideration of any one point of the area, but from a consideration of the whole area; hence the colour we observe is the mean colour. This, however, although very nearly, will not be exactly the same as at the centre. Suppose G to be the centre of a very small area, which we may denote by ds; then the quantity of light which passes through this small area towards the eye we may denote by ads. Since the area is very small, and ultimately vanishes, we may consider GF as the path of all the rays passing through this small area and reaching the eye. Let GF be denoted by x; then the intensity of the light after passing through the liquid will be $ak^x ds$, k being the coefficient of transmission. For simplicity I shall suppose k the same for every species of light, so that we need only consider one term of the above form. The small element ds we may regard as part of an elementary ring of area, $2\pi r dr$, where r denotes GE. The quantity of light passing through this ring towards the eye will be $2a\pi r k^x dr$. If then we integrate this between limits O and R, and divide by πR^2, we shall obtain the mean intensity. This will be

$$\frac{2a}{R^2}\int_0^R k^x r dr \qquad \ldots\ldots(1)$$

Let H be the elevation of the eye above the bottom of the cylinder, and h the height of the column of fluid; also let μ be the index of refraction, θ the angle of incidence, and θ' the angle of refraction. Then we have the relationship

$$\sin\theta = \mu\sin\theta' \qquad \ldots\ldots(2)$$

$$r = h\tan\theta + (H - h)\tan\theta' \qquad \ldots\ldots(3)$$

We may also write (1) in the form

$$\frac{2a}{R^2}\int_0^R \varepsilon^{-mh\sec\theta} r\,dr$$

The integration of this expression might be troublesome. Usually θ will be a small angle; suppose then that we neglect the cube. From (2) and (3) we deduce with this supposition

$$\theta = \frac{\mu r}{\mu h + H - h}$$

and the integral may be written in the form

$$\frac{2a}{R^2}\int_0^R \epsilon^{-mh(1+pr^2)} r\,dr$$

where p has been written for

$$\frac{\mu^2}{2(\mu h + H - h)^2}$$

we may also write it in the form

$$\frac{2a}{R^2} e^{-mh}\int_0^R \epsilon^{-mphr^2} r\,dr$$

The integral taken between the assigned limits is

$$\frac{a\varepsilon^{-mh}}{mR^2ph}\left(1 - e^{-mphR^2}\right)$$

If we expand the term e^{-mphR^2} and neglect terms containing the fourth and higher powers of R, we shall obtain for the mean intensity

$$ae^{-mh}\left(1 - \frac{mphR^2}{2}\right)$$

If, as is usual, H be large compared with R, the mean intensity would differ very little from the intensity of the central ray. An examination of the term $\frac{mphR^2}{2}$ will show if a correction is necessary in any case.

"Correction of the Formula used in Photometry by Absorption when the medium is not perfectly transparent," by James Bottomley, D.Sc., F.C.S.

Suppose we have a column of length l, containing q units of colouring matter per unit of length, the medium being perfectly transparent; then the light transmitted will be ak^{ql}. Now, suppose the colouring matter, instead of being uniformly diffused through the whole column, to be confined to an extremely small section at the bottom of length l', so that the length of the column above the section may be still taken as l. The intensity of the transmitted light will be the same in both cases; hence $k^{ql}=k^{q'l'}$.

If the medium be not transparent, we may now suppose the column of length l above the section containing the colouring matter to be occupied by some medium that absorbs light. Let ρ be its coefficient of transmission. The light incident on the bottom of the column is of intensity $ak^{q'l'}$. After penetrating the column the intensity will be $ak^{q'l}\rho^l$; but by what precedes, $q'l'=ql$; so that the intensity of the transmitted light corrected for absorption by the medium will be $a(k^q\rho)^l$. If, then, we have two cylinders containing q and q' units of colouring matter per unit of length, and columns of liquid l and l', we shall have the relationship $(k^q\rho)^l=(k^{q'}\rho)l'$. From this equation we may determine ρ in terms of k and known quantities thus:

$$\rho=k^{\frac{q'l'-ql}{l-l'}}$$

In some experiments on the absorption of light by carbon diffusions I noticed that when one diffusion was much stronger than the other there was a slight departure from the simple rule of colorimetry which held in other cases; this I thought might be due to the absorption of the water employed. The probability that this is the cause would be increased if the value of ρ deduced from one experiment, being applied as a correction to the other experiment, gave consistent results.

If we write ρ in the form k^p, the formula to be used may be written $(k^p k^q)^l = (k^p k^{q'}) l'$. This leads to the relation $(q+p)l - (q'+p)l'$.

The standard solution contained 1·2 cub. c. of a strong carbon diffusion in 500 cub. c. of water, and the length of column was 21·2. Comparing with this a solution containing 9·6 cub. c. in 500 cub. c. of water, on one occasion I made 2·94 the equivalent column, on another occasion 2·87, and on a third occasion 2·8. The mean of these three results is 2·87. Hence the corrected formula will be

$$(Q + 0 \cdot 114)l = (Q' + 0 \cdot 114)l'$$

Q and Q′ denoting the number of cubic centimetres of the strong diffusion added to each cylinder. In the following table I have recalculated the results given on page 197, Vol. XIX. of the Proceedings:

A	B	C
2·02	1·92	1·77
1·59	1·44	1·32
1·22	1·15	1·06
1·05	0·96	0·88
0·89	0·82	0·76
0·78	0·72	0·66

A denotes length of column by experiment, B denotes theoretical length calculated by corrected formula, C the theoretical length deduced from uncorrected formula. It will be noticed that the discrepancies between A and B are less than those between A and C.

"Note on the Colour Relations of Nickel, Cobalt, and Copper," by James Bottomley, D.Sc., F.C.S.

In a paper read before the Physical and Mathematical Section, April 13th, 1880, I referred to some experiments I had made to obtain a soluble black, and showed the advantages of such a solution in photometry, also its application to the determination of the law of absorption of light. The mixture used consisted of nickel, cobalt, and copper sulphates in acidulated water. In a paper read before the Chemical Society, May 19th, 1881, Mr. Thomas Bayley gives the results of some similar investigations. He also finds a mixture of nickel, cobalt, and copper sulphate suitable. The proportions of the metals in his solutions are:

Co.	Ni.	Cu.
1	1·48	2·16

The quantities of the salts used in the preparation of the fluid referred to in my paper give the following ratios between the metals:

Co.	Ni.	Cu.
1	1·49	2·46

General Meeting, October 18th, 1881.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

Mr. Thomas Gair Ashton, B.A., of Manchester, and Mr. Ludwig Mond, of Winnington Hall, Northwich, were elected Ordinary Members of the Society.

Ordinary Meeting, October 18th, 1881.

E. W. Binney, F.R.S., F.G.S., President, in the Chair.

"On the Failure of certain Mathematical Solutions of the Problem of the Motion of a Solid through a Perfect Fluid," by R. F. Gwyther, M.A.

Of the solutions with which I intend to deal, we may take that by Stokes for the motion of a sphere as the type. In his paper (Camb. Trans., vol. viii. and Reprint) Stokes considers to what degree his solution differs from the results of experience, and discusses the origin of this divergence. I propose to show that the origin is possibly of a different nature to any there discussed. Stokes' solution may be stated thus: If A be the centre of the sphere, of radius a, AX its direction of motion at time t, (r,θ) the zonal coordinates of any point in the fluid referred to AX as axis, and if ϕ be the velocity potential of the motion,

$$\phi = \text{const} - \tfrac{1}{2}\frac{Va^3}{r^2}\cos\theta$$

and

$$\frac{p-P}{\rho} = \tfrac{1}{2}\frac{a^3}{r^2}\frac{dV}{dt}\cos\theta + \frac{V^2a^3}{2r^3}\left\{(3\cos^2\theta - 1) - \frac{a^3}{4r^3}(3\cos^2\theta + 1)\right\} \text{.......(1)}$$

giving the fluid pressure.

To deduce from this the impulsive pressures due to an impulsive change in the velocity of the sphere, we write τ for the short time of action of the impulse, multiply equation (1) by dt and integrate from $t=o$ to $t=\tau$. Let V′ be the final value of V. The last term in p will contribute nothing to the final equation, and we obtain merely

$$\frac{\pi}{\rho}=\int_0^\tau \frac{p}{\rho}dt=\frac{1}{2}\frac{a^3}{r^2}(\mathrm{V}'-\mathrm{V})\cos\theta \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Now, the motion in question having been produced from rest in an infinite liquid by the motion of the sphere, the motion is the same at every instant as that impulsively produced from rest by giving instantaneously to the sphere its velocity V (Thomson and Tait, vol. i., part 1, page 328. Kirchoff, Vorlesungen, chap xix., &c.). The value of the impulsive pressures due to the instantaneous production of the velocity V of the sphere, and which produces the consequent velocities in the fluid is

$$\frac{\pi}{\rho}=\frac{1}{2}\frac{a^3}{r^2}\mathrm{V}\cos\theta \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where $-\frac{\pi}{\rho}$, of course, only differs from ϕ by a constant. Now, there need be no difficulty in supposing a fluid capable of transmitting a tension, provided this tension tends to produce no discontinuity of motion or disruption between near parts, as in the present case. But at the surface of the sphere we get

$$\frac{\pi}{\rho}=\frac{1}{2}a\mathrm{V}\cos\theta.$$

and thereupon a maximum of cohesion is needed of the order $a\rho\mathrm{V}$ at the extreme rear of the sphere, which is double the mean value required.* Considering the coefficient of cohesion as constant, all other things being alike, the velocity at

* The pressure in front, or tension behind a sphere of radius 1 foot, started impulsively with unit of velocity in water, would be roughly represented by that due to a slab of granite ½ inch thick falling through 3 inches.

which Stokes' solution would fail is inversely as the radius of the sphere, if failure can take place through want of cohesion.*

It becomes necessary now to consider the result of such a failure. In a perfect fluid, the consequence must be discontinuity, since we can not admit any minimum value of ϕ and therefore of π within the fluid. In a real fluid, on the other hand, the possibility of the fluid under the tension failing to exert pressure equally in all directions would have to be considered, as intermediate between the usual problem, and that of disruption, in either case vortex motion would ensue behind the solid.

"The Sea Gull in Salford," by William E. A. Axon, M.R.S.L.

During the recent storm a sea gull (*Larus canus*) which had been injured against the telegraph wires was picked up and cared for in the cottage at the Salford side of the Mode-wheel. It was unable to fly, though afforded opportunities of liberty, and appeared to be taking kindly to its new environment.

Sea-gulls are now rare visitants in this neighbourhood, but Mr. John Plant, F.G.S., saw two sailing over Peel Park in the earlier part of the year.

"On the Numerical Extent of Personal Vocabularies," by William E. A. Axon, M.R.S.L.

In the Bulletin of the Washington Philosophical Society, vol. ii., app. p. ii. (Smithsonian Miscellaneous Collections, vol. xx.) there is a paper by Prof. E. S. Holden, in which he gives some curious estimates as to the number of words used in speaking and writing. In order to test the matter he

* Or otherwise, consider the sphere to be brought to rest, the whole motion of the fluid will then cease, but in order to produce rest an impulsive tension of the magnitude named must be sustained at the surface of the sphere.

took Webster's Dictionary (1852), which contains 1281 pages of defined words—in all 92,488. He then examined the relative frequency of letters as initials, as words, and then found out the average number of words to a page. The next process was to go over the dictionary and to count all the words in the pages specially selected of which he had perfect knowledge, and which he would without hesitation employ. The result was that out of 4420 words he felt himself to have 1599 at full command. This proportion applied to the rest of the book would give Prof. Holden's vocabulary as 33,456 words.

Mr. Holden gives some other curious particulars. The Shakspere Concordance (in which verbs and nouns spelled alike are not discriminated) contains 24,000 words. The Concordance to Milton's Poems contains 17,377 words. The Bible contains 7209 words, exclusive of proper names. The Anglo-Saxon Chronicle contains about 12,000 words.

The results obtained by Prof. Holden seem to require verification by others before we can be sure that his is an average experience.

A friend has kindly gone over the ground for me, with the following results :—

		Total.				Total.	
A.	pp. 1—116	1199	422	L.	pp. 666—670	289	157
S.	„ 974—979	455	162	G.	„ 492—493	145	70
C.	„ 162—166	300	168	N.	„ 1210—1211	144	50
P.	„ 790—793	300	121	H.	„ 550—554	289	165
F.	„ 462—463	144	54	W.	„ 1248—1249	145	42
M.	„ 716—717	145	68	K.	„ 638—642	289	149
J.	„ 590—591	144	47	Y.	„ 1278	59	26
E.	„ 380—384	289	169	Z.	„ 1281	84	11
						4420	1881

My own counting reaches a somewhat higher figure than

Prof. Holden. Three personal vocabularies estimated in the same manner may be thus stated:—

J. J. Alley	37,000 words.
W. E. A. Axon	35,250 "
E. S. Holden	33,500 "

It is clear, however, that such a test as that applied by Prof. Holden is too strict. In the first place there is no absolutely complete list of the words in the language from which to deduce such a percentage. The existing dictionaries vary greatly in the number of words they contain.

It has recently been stated that the number in the best known is:

Johnson's Dictionary, Todd's Edition	58,000
Do. do. Latham's Edition, estimated	63,000
Webster's Dictionary (American), Early Edition	70,000
The Imperial Dictionary, Former Edition	100,000
Worcester's Dictionary (American), and Supplement, recently published	116,000
Webster's Dictionary (American), and Supplement, recently published	118,000
The Imperial Dictionary, New Edition	130,000

Then there are many words which we do not use habitually, but with which we are perfectly well acquainted, and which rise spontaneously to the lips when the fitting moment comes. There are also many words of a technical or special character which each individual possesses. The sportsman, not less than the chemist, has a language of his own. Then in the case of literary or scientific men their vocabularies must be largely increased by the knowledge of foreign languages, which is becoming increasingly common. For purposes of research a man must now have some acquaintance with French, Latin, German, and other languages.

The extent to which the human memory is capable of retaining words finds its highest expression in the case of Mezzofanti, whose remarkable linguistic powers are well known. It is established on tolerably conclusive evidence that he could write and speak in fifty languages. What would be the extent of his vocabulary?

General Meeting, November 1st, 1881.

Charles Bailey, F.L.S., in the Chair.

Mr. Alfred James Higgin, of Manchester, and Mr. Arthur Greg, of Eagley, near Bolton, were elected Ordinary Members of the Society.

Ordinary Meeting, November 1st, 1881.

Charles Bailey, F.L.S., in the Chair.

"On the Manufacture of Salt in Cheshire," by Thomas Ward, Esq.

The manufacture of salt has been carried on in Cheshire from the times of the Romans, and as the brine springs in several places rose to the surface or nearly so in early times, it is quite possible that the Britons may have utilised them. We have no record of salt making during the early Saxon times, though doubtless it existed, for in Domesday Book we find distinct records of salt works at the three "Wiches," Nantwich, Middlewich, and Northwich, and a reference is made to "King Edward's time," *i.e.* Edward the Confessor's. In 1132 Hugh Malbanc, in the foundation deed of Combermere Abbey says, "I grant to the same monks the fourth part of the town of Wych and tithe of my salt and the salt pits that are mine," &c.

From this period till the commencement of the 16th century the records are very scanty, but sufficient to show that the manufacture was still carried on at the three "Wiches." At this period the most important salt town was Nantwich or Wich Malbanc. Leland in his "Itinerary" and Camden in his "Britannia" both mention the Cheshire salt manufacture, and during the 17th century references are frequent, especially in the Philosophical Transactions of the Royal Society. Rock salt was discovered in 1670, and in 1721 the river Weaver was made navigable from Frodsham through Northwich to Winsford. After this period the manufacture steadily but not rapidly increased until 1825, when the duty was taken off salt. Immediately a great advance was made which continued till 1844, when the East Indian market was opened to English salt and the manufacture grew still more rapidly. The alkali trade caused another rapid advance so that at the present time the quantity manufactured is fully ten times as large as at the commencement of the present century.

The districts of Cheshire in which salt is made are in the valleys of the Weaver, Dane, and Wheelock, and this has always been the case, for with the exception of a small manufacture of salt at Droitwich for a limited time, none has ever been made except in close proximity to these streams. The Weaver valley is the most important, and at Winnington, Anderton, Marston, Wincham, Northwich, Leftwich, Winsford, and Nantwich salt is now being made, or has been made in times past. Since 1847 Nantwich has ceased to manufacture salt.

Middlewich is at the junction of the Croco with the Dane, which latter stream is a tributary of the Weaver. In the neighbourhood of Sandbach, at Wheelock, Lawton and the surrounding district, salt is made. These places lie in the Wheelock valley, a tributary of the Dane.

The Cheshire salt beds lie in the Keuper marls, though they are not co-extensive with these marls. The red or triassic marls of Cheshire lie in a kind of basin compared to an elongated saucer with its longest axis lying in a nearly north and south direction. The best known and most important beds of rock salt are about the centre of this basin in the neighbourhoods of Northwich and Winsford. At

Lawton in the south-east corner of the basin beds of rock salt have been found at a considerable height above sea level. At Northwich and Winsford the rock salt lies below the level of the sea. The Keuper marls of Cheshire are covered by drift. The clays, gravels, and sands of the drift are very much mixed up, and the clay is full of boulders of granite, and various kinds of stone, many of the softer kinds being deeply ice-marked or scratched.

In the early history of the salt trade, when but a very small quantity of salt was made, the springs at Northwich, Middlewich, and Nantwich either gently ran away into the rivers or rose nearly to the surface. When the rock salt was discovered near to Northwich in 1670, a strong brine was found running upon the surface of the salt. This brine was utilised at once, being stronger than that of the natural springs. On the banks of the Weaver many brine wells were sunk, and since that time all the white salt manufactured has been made from the brine thus discovered. Neglecting minor thin seams of salt which are met with either above or below the main beds, we may say there are two thick beds of rock salt known locally as Top Rock salt and Bottom Rock salt. These two beds are separated by a layer of marl much indurated and containing veins of salt running nearly vertically, as if occupying rifts, or cracks, or crevices in the hardened marl. This layer is about 30 feet thick. The first bed of rock salt, or the "Top Rock," is at Northwich from 40 to 80 yards from the surface, varying with the different surface levels and dipping from the N.E. to S.W. The surface of this salt bed is very irregular, being water-worn and channeled as if by miniature streams. In most cases immediately before reaching the salt a much indurated marl is found, locally termed "flag." On piercing this flag brine was met with in the first instance, and continues so to be to the present day.*

* At Nantwich this "flag" has been met with in a boring for brine now being carried on.

Brine is formed by fresh water reaching the surface of the salt either at the so-called outcrop or through fissures and faults in the marl. The marl itself, when unfissured or undisturbed, is perfectly impermeable. It is pretty certain that the water gains admission at a higher level than the rock salt, for the brine originally rose nearly to the surface of the ground in some districts, and in others rose many yards up the shaft when the "flag" was pierced. Brine is only met with on the surface of the Top Rock salt, which salt averages about 25 yards in thickness in the neighbourhood of Northwich. At Winsford the Top Rock salt lies more than 60 yards from the surface, and is rather thicker than at Northwich, though the indurated clay separating the two beds of salt is about the same thickness. The bottom bed of rock salt is about 35 yards thick at Northwich and rather more at Winsford. No water is ever found on this salt. The "Rock Head," as it is called, is perfectly dry.

It is almost impossible to say what the area of these beds of rock salt is. Judging, however, by the subsidence of the land, and taking into consideration the furthest points at which salt has been proved by shafts, I have come to the conclusion that the Northwich beds occupy at least three square miles, and contain in the aggregate about 900,000,000 tons—the upper bed 380,000,000, the lower 520,000,000. The Winsford district is more difficult to determine, but, being again guided by the distinct subsidences of the land, there cannot be less than six miles of salt beds containing at least 1,900,000,000 tons of salt. It is quite impossible to estimate the quantities of rock salt in the Nantwich, Middlewich, and Lawton districts, as there are no mines; and only in Lawton has the salt rock been bored through. There are several other districts where salt must exist as is shown by the subsiding of the land. The figures given, which are the merest approximations, show that practically the salt beds are inexhaustible.

The first, or top rock salt, was discovered in 1670, and very shortly after this mines were worked, but not to any large extent. It was not until 1721, when the river Weaver was made navigable, that the rock salt could be largely utilised. In the year 1732 there were sent down the Weaver 9,322 tons of rock salt. The quantity shipped down the river increased year by year until in 1778 it reached 54,000 tons. In 1781 the bottom, or lower rock salt, was discovered, and all new mines were sunk to it, the quality being better. After the commencement of the present century the top mines ceased to be worked, and now only one is known to exist. Nearly the whole of these top mines were destroyed by the breaking in of water or brine at the shafts. One after another they collapsed, leaving large funnel-shaped pits filled with water, locally known as "rock pit holes," to mark their position. In all the upper mines large pillars, about 5 yards square, were left to support the roof. In the lower mines these pillars, though originally of the same size, are now left larger, varying from 8 to 12 yards square. One or two lower mines have collapsed by the roof falling in for want of sufficient supports. Some have been abandoned because of the breaking in of brine or water. Of late years, however, when worked to the boundary of the owner, they have been allowed to fill with brine, which is pumped out for the manufacture of white salt. About 150,000 tons per year of rock salt are mined from the lower portion of the salt bed, which is the purest. This is not quite one tenth of the quantity of white salt made from brine. Whether, however, the salt is mined as rock salt or is manufactured from brine, the beds of rock salt before described furnish the whole.

The manufacture of salt from natural brine is carried on more largely in Cheshire than in any other portion of the world. The brine is found upon or near to the surface of the first bed of rock salt. It is reached by the sinking of a shaft or huge well, sometimes as much as 10 feet in diameter, which is cylindered to keep out the fresh water. Till recently there has been no great diminution in the quantity of brine. As soon as the 'flag' overlying the 'rock head' was pierced the brine rose very copiously and the most rapid pumping only produced a slight change of level. The height of the brine above the surface of the rock salt varied in all the districts, but in every case was considerable, being frequently 50 yards. The level of the brine when at rest or unpumped has fallen very considerably of late years, owing to the enormous increase in the make of salt. At Winsford the level in 1880 was 20 yards lower than in 1865. It is evident that more brine is being pumped out than fresh water getting in to make new brine to replace it. Many shafts have been completely exhausted.

Of late years a number of old worked out mines in the lower bed of rock salt have been used as reservoirs into which the brine from the rock head runs night and day. These enormous reservoirs are nearly always full, and in the majority of cases the brine rises high up the shafts. The mines in the bottom rock salt vary from 100 to 112 yards from the surface, and the salt is worked out to a depth of about 15 feet. Some of these reservoirs will hold more than 50,000,000 gallons of brine. Every day the trade consumes more than 4,000,000 gallons in making white salt. This enormous consumption has produced very startling results which I shall refer to later on. The brine is pumped up by means of powerful steam engines into reservoirs or tanks, and from these it is distributed to the pans through pipes.

The specific gravity of fully saturated brine is about 1·2, and it contains 26 per cent of salt. Roughly speaking, the Cheshire brines consist of 1 part salt, 3 parts water. The business of the salt manufacturer is to drive away the water and to retain the salt. This is done by heat, and the *rationale* of the process of making salt is extremely simple. When brine is fully saturated there is a state of equilibrium as it were. If we reduce the quantity of water this balance is disturbed and a portion of the salt crystallizes out, until the brine is again at saturation point. If we continue driving off the water the salt continues to crystallize and deposit. This process might go on till all the water was expelled and all the salt crystallized; but in the process of manufacture this never occurs, as the pan is replenished with brine from time to time.

During the manufacture of salt the laws regulating the formation of salt crystals may be clearly seen. The kinds of salt manufactured do not vary at all in their constituent parts, but merely in the size of the crystal or "grain," as it is called. To sum up the whole process in a few words, we may say generally that the larger the crystal the less the heat and the longer the time required to make the salt; the smaller the crystal, the greater the heat, and the less time required to make the salt. Brine boils at 226° Fahrenheit. Boiled salts are taken out of the pan two or three times in twenty-four hours. Common salt, such as used for soaperies, chemical works, &c., every two days. Fishery salt remains in the pan, according to the grain, from six to fourteen days; Bay salt, three weeks to a month. The manufacturer, by manipulating his brine, can make the crystal more or less flakey, or more or less solid as he wishes, but the general principle is not altered. Foreign ingredients, such as gelatinous matter, or alum, have very peculiar effects on the brine and on the salt crystal. Bay salt is made at a temperature of about 90°; Fishery, from 90° to 140° according to grain. Common salt, 170° to 180°. There is no exactitude maintained on this point, nor is it material, as a slight variation in the grain makes no difference in the sale and use of the salt.

The manufacture of salt is extremely simple, almost rude; yet the simple plan in use for ages has been found to answer best in the long run. The price of salt is so low, and the manufacture such a bulky one, that costly and elaborate apparatus has never been found to answer. Comparing the life of an ordinary open salt pan, such as is used in the trade almost universally, with that of any of the numberless patented pans that have been tried, it has been found that it costs less to manufacture salt by it, and that the pan is far easier to repair.

The pans used in the manufacture of salt are made of wrought iron, and riveted together like boilers. Under each pan are three or four fires, extending about five feet from the front of the pan. The pans are set upon brickwork, and the flues are continued under the whole length of the pan and thence lead to the chimney. Occasionally there is a chimney to each pan, bnt more often one chimney answers for several pans, as many as 16 fires often being connected with one chimney. The pans used for boiling the fine salts rarely exceed 33 to 35 feet in length, or the brine could not be kept boiling all over the pan. The surplus heat which in the coarse salt pans would be utilised to make salt for another 30 or 40 feet is passed under what is called the hot-house, where the boiled salt which is made into lumps or loaves is dried. Over this stove is a loft or storing room where the lump salt is kept dry and warm. The quantity of fuel consumed in making salt is very large. For making a ton of common coarse salt about 10 cwt. of slack or other cheap fuel is used. For making a ton of boiled salt about 13 cwt. of 'burgey' or 'through' coal is used. It is found that ordinary slack will not get up and maintain heat enough to keep the pans boiling.

The number of pans now in existence in the various salt districts is as follows:—

Winsford	638	
Northwich	458	(At Droitwich 151 pans).
Middlewich	13	
Sandbach	69	
	1178	

The quantity of white salt manufactured annually in each district is in round numbers :—

Winsford	1,000,000	tons.
Northwich	600,000	„
Middlewich	20,000	„
Sandbach	100,000	„
	1,720,000	„

The first pans used in the manufacture of salt of which we have any record were made of lead. A sheet of lead about ¼ inch thick and 2 feet 8 inches square, in the case of a pan in my possession, was obtained and bent up at the sides, and the corners hammered together. This pan was from 3 to 4 inches deep.* Six of these pans were usually set over flues in a small room. The contents of these six pans or "leads," as they were called, formed the unit of measurement in the salt trade when every maker was regulated by laws as to quantity of brine, time of taking it, hours of drawing salt, &c. So strict were the laws that an officer called a "Pan cutter" was employed to see that all the pans conformed to the standard pan. If any were larger he was to cut them down. After a time four pans took the place of the six, and were of equal capacity in the whole. Dr. Jackson, about 1668, describes these four pans as made of iron and superseding the six leaden ones. Their size, he says, was about a yard square and about 6 inches deep, and they held 28 gallons. In Dr. Brownrigg's time, 1765, the pans held 800 gallons, and Jars says the largest pans at Northwich, in 1765, were 20 feet long by 9 or 10 wide, holding about 1,100 gallons. Now the small pans used for boiled salt, which are the smallest in the trade, are from 25 to 35 feet long by from 20 to 24 wide, and 15 to 18 inches deep, averaging 5,000 gallons to the pan. The pans used for making coarse-grained salt vary from 50 to 70 feet in length—some few being even longer than this—and about

* There is an old lead in Warrington Museum, found at Northwich. It measures 3 feet 8 inches on greatest length, and 2 feet 8 inches in width, being 4 inches deep. It would hold about 20 gallons at most. The old pan in my possession, which is 25 inches square by 3 inches deep, would only contain about 7 gallons.

25 feet in width, the depth being 18 inches. These would contain over 16,000 gallons. The growth in the size of the pan has been equalled by the growth in the manufacture of salt, and most probably the increasing demand stimulated the maker to increase the size of the pan.

We have no statistics showing the quantity of salt made in early times. Judging, however, from the size of the pans or leads, there could not be much manufactured. The possession of a house containing six leads was of quite sufficient importance to be mentioned in Domesday Book as belonging to certain towns or villages. Many of the salt houses in the "Wyches" belonged to noblemen, and appear to have been used to make salt for their houses, for we read, "There is in Wych half a salt house to supply the Hall." In 1605 we read in an old letter, "There is in the said Towne (Northwich) one hundred and thirteen salt houses every one containing four leads apeece . . . and one Four leads which was given to the Earl of Derby . . . for the portion of his house."

From an estimate made about 1675, by William Lord Brereton, it would seem that about 305 tons 7 cwt. of salt were made at Northwich weekly; 107 tons 10 cwt. at Middlewich; and 105 tons at Nantwich. Thus, the total Cheshire make would be about 26,927 tons per annum. The whole of this was for the home trade. In 1732 only 5,202 tons of manufactured salt were shipped down the river Weaver, made navigable in 1721. None of this came from Middlewich and Nantwich, but from Winsford and Northwich. In 1801 this had reached 142,675 tons per annum. In 1820 we find 186,666 tons sent down the Weaver. In 1825 the salt duty was taken off, and in 1830 the quantity sent down the Weaver reached 312,012 tons in the year, and in 1840 414,156 tons. In 1844 English salt was allowed to be sent to the East Indies, and the result is seen by the exports down the Weaver reaching 607,395 tons in 1850. During the next ten years the increase was not large, but as soon as the alkali trade began to extend the manufacture of salt increased, and in 1870 we find 991,158 tons sent down the Weaver, which reached 1,087,214 in

1880. It will be seen from these figures how rapidly the salt trade has increased in the last half century. As the Weaver is only one line of communication (though the chief one) by which Cheshire salt leaves the county, there being canals and railways taking large quantities, the figures above given do not show all the trade. The following table of salt exported from the Mersey ports—viz., Liverpool, Runcorn, and Weston Point, which I have compiled from the official statistics, supplied to me for the ten years ending December 31st, 1880, will show the countries taking Cheshire salt, and the quantities supplied to each:—

Countries.	White Salt. Tons.	Rock Salt. Tons.
United States (North and South)	2,118,656½	18,827
British North America	691,186¼	31,354¾
West Indies and Central America	40,003¼	757½
South America	34,640	2,258¾
Africa	246,429	746¾
East Indies	2,552,856¼	155
Australia and New Zealand	139,510¼	26,943
Germany	345,229	1,026
Russia	581,501¾	23,697
Norway, Sweden, Denmark, and Iceland	197,299¼	39,636
Belgium and Holland	81,633	644,471
France and South of Europe	17,699	943½
England	840,285	135,371
Ireland	469,310	64,155
Scotland	711,229½	19,631
Total	9,067,468	1,009,973¼

This table is a very interesting one, but I must not discuss it, as it affords material enough for a paper in itself. Besides the salt thus exported, we must reckon at least 500,000 tons of white salt and 30,000 tons of rock salt sent into the interior by canal and railway yearly. During the last three years the make of white salt, in Cheshire, cannot have been much short of 1¾ millions of tons per annum.

It may be interesting here to speak of the price at which salt sells at the works. In using the expression "at the works" it must not be understood that salt is sold delivered at the works. The usual rule is to sell delivered at the port of shipment, or if in the country at the place where required; but to avoid all complications arising out of varying rates of carriage and freight, it is customary to sell at a 'works' price and add on the freight or carriage. The salt that generally regulates prices is common salt, which is the cheapest and most largely used of any. Taking the price of common salt as a standard, the other salts as a rule vary according to the following table. When prices rule high the difference increases, and when they rule low it is rather less, but on the average the prices here given may be considered the usual ones.

With common as the standard:

	s.	d.	
Butter, or unstoved boiled salt, is......	1	6	per ton more.
Shoots, or broken stoved boiled salt...	3	0	,, ,,
Handed squares stoved salt......5s. to	6	0	,, ,,
Fishery or coarse salt (according to quality)..................1s. 6d. to	5	0	,, ,,

Bay salt and refined table salt being made only in very small quantities fetch prices not regulated by any other qualities, varying from 30s. to 50s. per ton.

The following table will show the fluctuations in common salt or the standard salt, for ten years:—

Average price.	Per ton. s.	d.	Highest. s.	d.	Lowest. s.	d.
1871	6	1	7	0	6	0
1872	12	4	20	0	7	0
1873	14	8	15	0	12	0
1874	10	0	12	0	8	0
1875	8	6	9	0	6	6
1876	6	5	8	0	5	0
1877	5	6	7	0	4	6
1878	6	6	7	0	5	0
1879	5	6	7	0	4	6
1880	5	6	6	6	4	6

During 1881 the price has been, on the average, only 4s. 9d.; and stoved salts for India have ruled lower than at any former period.

It would be interesting to point out the various kinds of salt made, the purposes for which made, and the countries to which sent—also to show the bearing of the salt trade upon the general trade of the country, and more especially upon the shipping trade of Liverpool. This, however, must be left for another paper, if thought desirable.

The most remarkable feature in connection with the manufacture of salt is the extensive subsidence of land, and the great destruction of property caused by it. In mining the rock salt in the usual way, that is by blasting and picking, an ordinary mine is formed subject to the usual mining accidents of water breaking in, or the roof falling. There is no bad gas to cause explosions. It is not accidents of this kind that are referred to in speaking of land subsidence in the salt districts. The whole of the manufactured salt is literally mined by water. A constant stream of water running over the rock salt to the pumping stations becomes saturated with the salt that it takes up on its way. Being pumped up, the salt is gained by the method of evaporation before described. It is evident that in gaining the salt in this manner, by water, no provision can be made for the support of the roof of overlying earths, as is done by pillars in the ordinary mine. The brine streams, or brine 'runs' as they are called, resemble brooks and rivulets into which the waters run from all sides and drain the surface. The course of these underground streams is marked by a corresponding depression on the surface of the ground. The land sinks more rapidly directly over the brine runs than elsewhere, though there is a gradual lowering of the surface of the rock salt generally, even out of the line of the runs—exactly as there is a gradual lowering of the surface of the land by the solid earths and sands carried away by the water draining off it. The salt, however, being so much more soluble than earths, the process is much more rapid. In some cases the overlying earths follow the gradually wasting rock salt continuously, and the subsidence on the surface is regular and continuous; in other cases where there happens to be a tenacious "flag" or other stiff and solid earths, the superincumbent mass remains suspended over the brine run for a long time. As soon, however, as the weight of the suspended mass overcomes the tenacity of the marl or flag, a sudden sinking of the whole overlying earths takes place, and a large hole reaching up to the surface is formed, which in time becomes filled with water.

In recent years a number of these holes have been formed in the neighbourhood of Winsford and Northwich. In the neighbourhood of Northwich they have been formed chiefly over old mines. Instead of the hollow being made naturally, as near Winsford, by the ordinary brine run, it has been made artificially by the miner. In both cases, however, the sudden sinkings are directly caused by the pumping of the brine. Whenever any sinking, whether gradual or sudden, occurs in the neighbourhood of a brook or river, and the majority occur in such positions, the water soon fills the hollow thus formed and tiny lakes commence which go on increasing. The local name for these lakes is "Flashes." At Northwich the "Top of the Brook," as it is called, now covers about 100 acres. At Winsford the Top and Bottom flashes cover about the same area, whilst both at Winsford and Northwich new lakes are rapidly forming. Near Winsford one called the Ocean covers about eight acres. At Marston, near Northwich, there is one covering ten acres when the water is at its greatest height. On Dunkirk, near to Northwich, the scene of the great subsidence of December 6th, 1880, the hole then formed is rapidly extending, following the course of the Peover Brook. About two miles from Northwich, at Billinge Green, away from any salt works, a subsidence has begun and is rapidly extending, a lake having commenced which is only about an acre in extent, though more than 100 acres show signs of subsidence. In the Winsford and Northwich districts more than 1,000 acres in each show distinct traces of subsidence, and in both cases the towns and buildings suffer to a most serious extent. How seriously owners of property suffer will be seen from the statistics given here, which I have taken from the evidence given before a Committee of the House of Commons in May last:

Approximate number of persons as owners injuriously affected	418
Public Buildings damaged	11
Salt Works damaged	22
Slaughter-houses, Stables, and Out-buildings damaged	40
Warehouses, Workshops, &c., damaged	46
Public Houses damaged	56
Shops damaged	202
Houses and Cottages damaged	931
Total Buildings affected	1308
Area of land affected (acres)	2808

The value of the property affected (exclusive of railways and canals, which suffer seriously) in its damaged state is estimated at £480,000. The amount of depreciation in value is estimated at £168,500. To keep this property in a good state of repair would require on the average £18,000 per annum. In this estimate, besides omitting railways and canals, no account has been taken of the expenditure of the Local Boards and Highway Boards in maintaining their roads and sewers—nor yet of the county authorities in the repair of bridges, nor of the gas and water companies in repairs of pipes and loss of gas and water. For all this destruction of property there is no legal remedy, and no compensation whatever is paid.

The owners whose property suffered so severely applied to Parliament to obtain a Bill called "The Cheshire Salt Districts Compensation Bill." The object of this Bill was to obtain compensation from the salt manufacturers for the damage caused by the abstraction of the salt in the form of brine. There was no attempt made to obtain payment for the salt taken, but merely for the damage done to the property overlying the salt. The Bill was not obtained owing to many serious difficulties that would arise in carrying it out, but chiefly owing to a very ingenious line of defence set up by Mr. De Rance, a geologist connected with the Ordnance Survey Department. He contended that the enormous subsidences at Winsford were produced naturally by the same causes that produced the Cheshire meres, and that the Northwich subsidences were caused by bad mining. In my opinion—based upon a far more extensive examination of these sinkings than that made by Mr. De Rance, and formed on the spot with the sinkings proceeding daily before me for a number of years—Mr. De Rance's theories are wholly untenable. To attribute to ordinary geological causes, which in almost every case work slowly and continuously, the enormous subsidences of the last 50 years, and more especially those of the last 10 years, and which have gone on increasing in the direct ratio of the increase in the manufacture of salt, when there is an artificial cause at work patent to every one, tends to injure science in the eyes of those who know the whole history of these sinkings. The manufacture of salt in Cheshire is interesting archæologically, historically, commercially, and geologically, and it is impossible to do full justice to it in one short paper.

Ordinary Meeting, November 15th, 1881.

E. W. Binney, F.R.S., F.G.S., &c., President, in the Chair.

"On the Pronunciation of Deaf-Mutes who have been Taught to Articulate," by William E. A .Axon, M.R.S.L.

At the meeting of the French Academy of Sciences on the 7th, M. Felix Hément stated that his observations had led him to the conclusion that the deaf and dumb who have been taught to speak, do so with the accent of the district in which they were born, rather than with that of their teachers or associates. This was discredited by M. Blanchard, but some curious facts tending in the same direction have already been recorded. In the "Philosophical Transactions" (No. 312), there is the following case. About the age of seventeen, a young man, a congenital deaf-mute, was twice attacked by fever. "Some weeks after recovery, he perceived a motion of some kind in his brain, which was very uneasy to him, and afterwards he began to hear, and, in process of time, to understand speech. This naturally disposed him to imitate what he heard, and to attempt to speak. The servants were much annoyed to hear him. He was not distinctly understood, however, for some weeks; but is now understood tolerably well. But what is singular, is, that he retains the Highland accent, just as Highlanders do who are advanced to his age before they begin to learn the English tongue. He cannot speak any Erse or Irish, for it was in the Lowlands he first heard and spoke." The curious circumstance of his possession of the Highland accent is confirmed by the testimony of similar phenomena in Spain. "One fact," says Ticknor, "I witnessed, and knew therefore personally, which is extremely curious. Not one of the pupils, of course, can ever have heard a human sound, and all their knowledge and practice in speaking must come from their imitation of the visible mechanical movement of the lips, and other organs of enunciation by their teachers, who are all Castilians, yet each speaks clearly and decidedly, and with the accent of the province from which he comes, so that I could instantly distinguish the Catalonians and Biscayans and Castilians, whilst others more practised in Spanish felt the Malagan and Andalusian tones."—("Life and Journals of George Ticknor." London, 1876, Vol. I., p. 196). A similar case has been mentioned to me by Mr. J. J. Alley of Manchester. E. R. became deaf and dumb at a very early age, and did not talk until he was about seventeen, when he was taught articulation by Mr. Alley. He speaks with the accent of his native county of Stafford. These instances are cited in my paper on the Education of the Deaf and Dumb, in the Companion to the Almanac for 1880.

"On Professor C. A. Bjerkness's Experiments to Demonstrate the Analogies between Electrical and Magnetical Phenomena and some Hydrodynamical Phenomena," by WILLIAM H. JOHNSON, B.Sc.

Among the many interesting exhibits at the Paris Electrical Exhibition, there is nothing more likely to engage the attention of the scientific observer than the simple apparatus and experiments of Professor Bjerkness, of the University of Christiania.

The apparatus consists in the main of metal spheres about one inch in diameter, and drums also an inch in diameter with indiarubber ends. These spheres and drums communicate by means of indiarubber tubes with a pair of air-pumps, which, by an ingenious contrivance, cause the spheres to oscillate and the drums to pulsate isochronously. If the two air-pump pistons go in and out at the same time, the spheres connected with them will oscillate concordantly. If on the other hand one piston goes in while the other comes out, the respective spheres connected with the air-pumps will oscillate in opposed phase. The same will take place with the pulsating drums.

When these spheres and drums are allowed to oscillate and pulsate rapidly in a vessel of water, they are found to attract each other if they vibrate in accord, and to repel each other if the vibrations are opposed. Nor is this all, for Professor Bjerkness, by carefully modifying his apparatus, which has been very imperfectly described above, has been able to imitate all the phenomena of magnetism and paramagnetism, but always in an inverse way.

Many phenomena of statical and dynamical electricity can also be imitated by these vibrating bodies, but likewise in an inverse manner.

The whole subject has been investigated mathematically by the Professor, and the laws which govern the attractions and repulsions of these vibrating bodies have been shown to be in accordance with his formulæ.

General Meeting, November 29th, 1881.

R. Angus Smith, Ph.D., F.R.S., &c., in the Chair.

Mr. Richard Peacock, of Gorton Hall, Manchester, and Mr. Edmund Salis Schwabe, of 41, George Street, Manchester, were elected Ordinary Members of the Society.

Ordinary Meeting November 29th, 1881.

R. Angus Smith, Ph.D., F.R.S., &c., in the Chair.

The following letter from Mr. Joseph Sidebotham, F.R.A.S., was read:

"Some few years ago when I was at Mentone, I wrote to you concerning the aniline colours, so much used on the Continent in water colour drawings. Since that time Holman Hunt and others have called attention to the fading of these and some other colours prepared for artists, and I hoped the practice of making and using these colours had ceased; however, I find this is not the case. A friend of mine was on his way to the South of France, and I asked him to see if these colours were still sold and used, and he tells me they are extensively, and sent me cakes of them; he also sent the enclosed sheet of the colours on drawing paper, half of it having been exposed to the light, a fortnight, the other half covered up. He thought that by putting gum over the colours they might be made more permanent, and you will see he has put a band of gum across them; the colours exposed have faded in a great degree, some of them almost disappearing. The band of gum has retarded the fading, but the colours are even there much lighter and all the brightness gone. It is most desirable that artists should entirely give up the use of all these colours, and then the makers would cease to supply them. When we see the sad effects of a fortnight's light upon them, what can we expect to see in drawings hung on the walls of a room for a few years?"

"On Cyclic Motions in a Fluid, and the Motion of a Vortex Ring of varying Curvature," by R. F. Gwyther, M.A.

The possible kinds of fluid motion are divided into irrotational, which is either cyclic or acylic, and rotational or vortex motion. In treating of the motion of a perfect fluid it is usual to consider the cases of acyclic irrotational motion and of vortex motion, considering cyclic irrotational motion as an adjunct of the second. This appears to me to be an improper division of the subject, which should rather be treated in the inverse manner, since the result is that the phenomena which are actually due to the cyclic nature of the motion are sometimes attributed to the vortex motion.

In cyclic motion the circulation in any circuit is either zero or constant according to the nature of the space which the circuit encloses. If the circulation in a circuit is not zero, the circuit either encloses a portion of space not occupied by the fluid, or a portion of fluid, either terminating at a boundary of the fluid or bounded by a closed surface, for which no velocity potential exists. Let u, v, w denote the components of the velocity at any point in the fluid, and $\int ds$ denote integration completely round a closed circuit. Let $\int dS$ denote integration over any portion of surface bounded by the circuit, of which a portion may consist of the bounding surface of the fluid, and let l, m, n be the direction cosines of any portion dS of this shell. Then by a Theorem due to Stokes, the circulation in the circuit may be written

$$\int\left(u\frac{dx}{ds} + v\frac{dy}{ds} + w\frac{dz}{ds}\right)ds = \int(l\xi + m\eta + n\zeta)dS,$$

whence if the surface S can be drawn without passing out of the space occupied by the fluid, and if the integral does not vanish, ξ, η, ζ must have values different from zero at some portions of the suface S. Also the integral has the same value for all surfaces S drawn; therefore the strength of the vortices on all surfaces bounded by the circuit is the same, and if the vortex lines are capable of being cut at right angles by a surface, is equal to the total strength of the vortices.

If the space be polycyclic the circuit can be replaced by a number of monocyclic circuits for each of which the circulation in the circuit, or the cyclic constant, is equal to the strength of the enclosed vortex tube upon any surface drawn bounded by the circuit. We have therefore shown that cyclic motion requires the space in which it exists to be made multiply continuous either by solid boundaries or by vortex filaments.

Cyclic motion is therefore a condition of space, and vortex motion is a result of it. Cyclic motion can be produced by suitable impulses applied as shown by Thomson (Vortex Motion, Trans. Edin., R.S.), and vortex motion in a perfect fluid can only appear as a consequence, either of cyclic or discontinuous motions.

Since the cyclic constant can not be a function of the time, we also infer

$$\int\left(l\frac{d\xi}{dt}+m\frac{d\eta}{dt}+n\frac{d\zeta}{dt}\right)dS=0.$$

But from this we may not conclude that the vortex motion is steady in the sense that it is always the same at the same point in space. For if the circuit retained a fixed position in space, the portion of fluid moving rotationally might move out of it. The true conclusion is that while the core of vortex motion remains within any circuit the strength of the core on any shell experiences no variation with the time, and as the circuit may at any time be replaced by a reconcileable circuit, this theorem may be extended to all space.

Again, since $D_t\int\left(u\frac{dx}{ds}+v\frac{dx}{ds}+w\frac{dz}{ds}\right)ds=0$, we may conclude that a circuit which embraces a core of vortex motion moves so as to continue to embrace the same core the same number of times. As each circuit may be diminished by the substitution of reconcileable paths, we may apply this to the simplest circuits embracing a core. We thus arrive at the known properties of vortex motion accompanying cyclic motion.

The observed phenomena of rings, whether these be vortex rings or material rings which make space multiply continuous, are the effect of the cyclic motion. It is an object of this paper to notice the motion of the ring itself as the consequence of the cyclic motion.

The energy of a cyclic motion may be written (Lamb's Hydrodynamics, Art. 136)

$$T=2\iiint\left\{u(y\zeta-z\eta)+v(z\xi-x\zeta)+w(x\eta-y\xi)\right\}dx\,dy\,dz$$

and evidently depends on the size and shape of the necessary vortex filament. To find in what way a portion contributes to this energy by its motion, take the origin on a vortex line, the tangent line as axis of z, the principal normal as axis of x, and the binormal as that of y, and consider the part of the integral between $s=-l$ and $s=l$. When we put

$$x=x_1+\frac{s^3}{6\rho\tau},\ y=y_1+\frac{s^2}{2\rho}\quad z=s-\frac{s^3}{2\rho^2}$$

x_1 and y_1 denoting the coordinates of a point in the section of the filament in the plane of xy,
we obtain

$$2\int\int_{-l}^{l}\left\{u\left(y_1+\frac{s^2}{2\rho}\right)-v\left(x_1+\frac{s^3}{6\rho\tau}\right)\right\}\zeta ds\,da$$

$$=4Ul\int y_1\zeta da-4Vl\int x_1\zeta da$$

$$+\frac{2U}{3\rho}l^3\int\zeta da$$

when U and V are the mean resolved velocities of the element.

If the core be of symmetrical section, the first two of these integrals will vanish, and the term contributed to the energy will contain only the velocity along the principal normal.

The total energy will depend upon the size and shape, as said before; but we can conclude that if the filament be of symmetrical section, the motion of each portion will be along its principal normal. In the case of a straight filament this term would vanish, and in the case of a circle would be the same at all points—thus agreeing with the two cases which have been worked out.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

October 10th, 1881.

Alfred Brothers, F.R.A.S., President of the Section, in the Chair.

The President alluded to the death, in April, of Arthur George Latham, Esq., and a vote of condolence with Mrs. Latham was unanimously passed.

Mr. Marcus M. Hartog, B.Sc., F.L.S., made some remarks upon damaged Indian rubber, and pointed out the advisability of treating it with a solution of magenta. This stains it most strongly where most damage has occurred.

Mr. J. Boyd reported upon some parasites affecting the partridge, and the eggs were found amongst the feathers below the beak, just where the bird was unable to touch them. These eggs he afterwards exhibited under the microscope, and also a living specimen of the parasite, which was a species of Acarus.

Mr. Boyd also mentioned the capture by him of the ♂ of leptodora hyalina, near Keswick, distinguished by the great length of its antennæ from the ♀ at a glance.

A discussion on the proportionate rarity of the ♂ in the entomostraca and copepoda then ensued.

November 7th, 1881.

ALFRED BROTHERS, F.R.A.S., President of the Section, in the Chair.

A letter was read by the Secretary from Mr. Arthur Latham, in acknowledgement of the resolution of condolence on the death of his father, passed at the last meeting.

The following resolution passed at the council meeting of the Parent Society on 19th April was read:

"On the motion of Mr. R. D. DARBISHIRE, seconded by Dr. JOULE, it was resolved that the Associates of each Section be empowered to vote in the election of officers of the Section with the members, and that Associates may be eligible for the offices of the section."

The Secretary read a communication from Mr. Sidebotham, F.L.S., relative to a supposed marine species of alga (? fucus canaliculatus or ceranoides) which was growing on the window of his house at Bowdon. It was about half an inch in diameter, but was still increasing in size. It might have originated from a spore blown by a west wind, and nurtured by the saline breezes that blow across from the Irish Channel through Runcorn Gap.

Mr. HARTOG, B.Sc., F.L.S., made some remarks on the result of his further investigation of the mode in which hydra viridis swallows its food. He had found that the endoderm cells of the tentacles possess a power of amœboïd motion by means of which they draw themselves over the object to be swallowed.

Mr. R. D. Darbishire, F.G.S., exhibited Tryon's mollusca and the atlas of plates to Prof. Hæckel's "Die Radiolarien."

Mr. Wills (who was present as a visitor) exhibited an interesting series of preparations of desmidiæ, and stated that when in Wales last year his father took a large gathering of desmidiæ from the stream as it flows out of the lower of the two Capel Curig lakes. They were embedded in mosses of the well known infusorian Ophrydium versatile and also in the accompanying weeds, and it is about some of the rarest found in this gathering that he remarked. But first he called attention to the fact that they were found in flowing water, not a usual situation; on this point Ralfs says "They are rarely gathered in streams, being unattached, and very minute, nevertheless, interesting species may occasionally be gathered where the current is so sluggish as to permit their retaining mucus to elude its force. The current in the case of these desmidiæ certainly was the reverse of sluggish.

In the slides shown, he pointed out many common species, but also several rare ones, some new to England, others new to the British Isles, and three new to science, one of which his father had successfully demonstrated to have been recorded for the first time last summer.

Those new to England but recorded before as Irish, Scotch, or foreign species are:

Spondglosium pulchellum (Archer)
Tetrachastrum mucronatum (Dixon)
Cosmarium cyclicium (Lundell)
" holmiense "
" nymamanum (Grunow)
" pseudo connatum (Nordstedt)
" pseudo pyramidatum (Lundell)
" truncatellum (Perty)
" variolatum (Bulu)
" globosum (Lundell)

Staurastrum Arctiscon (Lundell)
　　„　　Aversum　　„
　　„　　Cerastes　　„
　　„　　Cristatum (Nagele) Farsets
　　„　　longispinum (Bailey)
　　„　　saxonicum (Reinsch)
　　„　　paradoxum
　　　　　variety longipes (Nordstedt)
　　„　　pruigstemin (Reinsch)
Closterium cynthia (de Notaris)
　　„　　gracile (Brétisson)
Penium nâgeli　　„

Those new to the British Isles are:

Cosmarium Holmiense variety (Lundell)
　　„　　læve (Nordstedt and Wittroch)
　　„　　nitidulum (de Fotaris)
　　„　　pseudo nitidulum (Nordstedt)
　　„　　præmorsum (Brétisson)
Staurastrum Brasiliense (Lundell)
　　„　　grande　　„
　　„　　inflexum (Brétisson)
　　„　　megacanthum (Lundell)
　　„　　pseudo porciferum (Reinsch)
　　„　　sebalde (Reinsch)
Docidium nodosum (Bailey)

And those new to science are:

Cosmarium cambricum
Staurastrum anatinum
Cosmarium coronatum

On referring to a paper his father had written on this subject he found that no less than 150 distinct species of Desmidiæ were found at Capel Curig that summer.

The Staurastra and Cosmaria are both extremely difficult to identify, and the species ill defined, and it is often almost impossible to name them unless you get several aspects of the same object.

The way he found answered best in mounting these lovely little plants is, after he had washed and prepared them in the cell, to put them with a little *plain* water, place a glass cover over them, carefully avoiding the enclosure of any air bubbles, and having taken up any moisture about the edge of the cell with blotting paper, to seal them up with gold size. In some cases the colour goes, but in others the bright green colour is retained for many years.

In conclusion, he said there was a want among investigators in this branch of microscopic work of a uniform scale to which to make their drawings. Each man has his own scale, and this makes the comparing of drawings very much more difficult than if a uniform scale, say 400 diameters were adopted, by means of which one man might at once and without the slightest difficulty compare his drawings with those of other fellow-workers.

PHYSICAL AND MATHEMATICAL SECTION.

November 8th, 1881.

JOSEPH BAXENDELL, F.R.A.S., President of the Section, in the Chair.

"Note on a Passage of Pollux relating to the formation of Purple Dye," by JAMES BOTTOMLEY, D.Sc., F.C.S.

At a meeting of the Society on November 18th, 1879, I gave a short passage from Musgrave containing a quotation from Pollux. From this passage it was inferred that the ancients were in the habit of exposing purple garments to the sun to revive the colour. Since then I have referred to a copy of Pollux. The passage in question does not refer to the revival of the colour as Musgrave seems to think; it evidently refers to the initial action of light in generating the colour. Moreover, in quoting the sentence, he has left out at the end a few important words (*ἐκφοινισσομένην ἐκ τοῦ ἄνω πυρός*).

The Onomasticon of Pollux is for the most part a dry and uninteresting work. As it is not likely to be very accesible I have given the passage treating of the generation of the colour.

Ἐνέφουσιν ἐμπύρῳ λέβητι τὸ θήραμα τὸ θαλάττιον, τὸ δὲ αἷμα ἐπειδὰν πυρὶ ὁμιλήσῃ, χεῖταί τε καὶ ἐξανθεῖ καὶ τὸ μὲν ξανθίζεται, τὸ δὲ κυαναυγὲς γίγνεται, τὸ δὲ ἀλλο εἰς ἄλλην χρόαν τρέπεται, καὶ ὅ-τι ἂν καθῇς, πᾶν τὸ ξυγγενόμενον τῷ αἵματι, πρὸς τὴν αὐτοῦ χροιὰν μεταχρώννυται· χαίρει δὲ ἡλίῳ ὁμιλοῦσα τῆς πορφύρας ἡ βαφὴ καὶ ἡ ἀκτὶς αὐτὴν ἀναπυρσεύει καὶ πλείω ποιεῖ καὶ φαιδροτέραν τὴν αὐγὴν ἐκ φοινισσομένην ἐκ τοῦ ἄνω πυρός.

The Latin translator renders the passage as follows:

In fervente lebete animal marinum excoquunt, ceterum sanguis hic, ignis viribus conceptis, diffunditur et efflorescit, et hæc quidem ejus pars, flavum, illa nigrum, alia vero alium colorem induit; et quicquid immisseris, id sanguine commixtum, ejus colorem qualiscunque ille sit imbibit. Tinctura vero purpuræ solem amat, etenim hujus illustrata radiis majorem lætioremque splendorem purpureo colore coruscantem e supero igne concipit.

Liddell and Scott give as the meanings of the word *κυαναυγης* dark gleaming, dusky, obscure. These seem hardly suitable to the passage; probably dark blue would be nearer the meaning. The same authors also give as the meaning of *ἀναπυρσευω* to make more fiery or glaring, referring to this passage of Pollux as an example.

A nearly literal translation would be :—They digest the marine animal in a caldron over the fire, and the blood when it associates with heat liquefies and develops colour, and part becomes yellow, part dark blue (?), and another part changes to another colour. And whatsoever you dip in, everything that has come in contact with the blood is changed in colour to the colour thereof; but the purple dye rejoices in association with the sun, and the solar beam gives it fire and makes more intense and dazzling its splendour, which is rendered purple by means of the fire aloft.

Ordinary Meeting, December 13th, 1881.

J. P. JOULE, D.C.L., LL.D., F.R.S., &c., in the Chair.

"Remarks on the Terms used to denote Colour, and on the Colours of Faded Leaves," by EDWARD SCHUNCK, PH.D., F.R.S.

At the recent meeting of the British Association held at York, a paper was read by Dr. Montagu Lubbock before the section for anatomy and physiology on "The development of the colour sense," which I had the pleasure to hear. The purpose of the author was to controvert the opinion of those who hold that the colour sense in man was not always what it is now, but that it has gradually been developed, the last stages of this development having taken place within historical times. It is supposed that the human eye was originally only capable of distinguishing black and white, and that the capacity of seeing the various colours of the spectrum arose by degrees, red being the first and blue the last colour to be discriminated. Mr. Gladstone, in a paper published not long ago, goes so far as to say that the ancient Greeks, having no word for blue, were blind to that colour, and that it is only since their day that human vision has been so far developed as to perceive the more refrangible end of the spectrum. The author of the paper referred to arrived at the conclusion that there is no sufficient evidence to show that the faculty of perceiving colour has been acquired by man within historical times, a conclusion in which Sir John Lubbock, who took part in the discussion on the paper, entirely concurred. Whatever may have taken place in prehistoric times, there can be little doubt, I imagine, looking at the remains adorned with various colours in Egypt and elsewhere, that the more civilised nations of antiquity, though they had fewer pigments at their disposal than we have, were quite as capable of distinguishing colours as we are. It may indeed be asserted that so far as appropriate arrangement of tints in dress and other articles of daily use is concerned, no advance has been made since the time of the ancients, but rather that we have in this respect retrograded. Evolutionists tell us that we may obtain a good idea of what our prehistoric ancestors were, by observing the present state of savage and uncivilised races, a state from which we have in the course of ages emerged. So far, however, as the appreciation of colour is concerned no superiority on our part can be discovered, for whoever will, with an unprejudiced eye, compare the harmonious combinations seen in the articles produced by the less civilised nations of India and China, or by the natives of America and Polynesia, with the hideous contrasts and tasteless arrangements so often displayed in our articles of dress and furniture, will probably incline to the opinion that in this respect we may rather be called savages, and that the incapacity for appreciating colour harmony inherent in the Teutonic branch of the Aryan race has not been removed, but rather intensified by civilisation. Much has, indeed, been done of late to promote good taste in this as in other departments of art, though our progress has probably been retarded by the introduction of various artificial colouring matters, the extreme brilliancy of which acts as a lure to the uncultivated eye.

Though much of the uncertainty which exists as to the precise meaning of the words used by the ancients to denote colour is of a philological kind, part of it is due, I think, to causes which are still in operation.

1. The ancients, having no fixed scale of colour to refer to, such as we possess in the spectrum, were unable to compare any given tint with that which it exhibits in its highest state of purity, whilst we, by means of the fixed standard

at our command, and with the assistance of the so-called chromatic circles and other appliances, can determine not only the exact position and shade of any given colour, but also the extent to which it is degraded or rendered impure, and though the general public very slowly adopts scientific terms and methods, still on the whole the tendency in our days is towards exactitude, and vague terms for objects and sensations are more and more falling into disuse.

2. In one respect the ancients must have laboured under the same disadvantage in determining the value of colour, as we moderns do. We very seldom see one colour alone, but generally two or more in juxtaposition, and contrasted, and by contrast the effect of each colour on the human eye is considerably modified. Complementary colours, when seen in close proximity, heighten one another. Green next to red will appear much brighter than when placed close to blue. A colour of average purity will appear dull when compared with a brighter colour of the same hue, while it will seem bright when seen alongside a more dingy shade, and so on. Unless great care be taken, therefore, we are liable to become inaccurate when describing a colour, though on the other hand, it may be doubted whether, if the human eye were so constructed as to see only one of the colours of the spectrum, we should from the absence of contrast be able to appreciate that colour correctly.

To the fact that we almost always see colours in contrast must be ascribed the habit which men have of speaking of "beautiful colours." No one who has thought on the subject need be told that a simple sensation cannot be strictly speaking beautiful. It is only by combination, contrast, and harmony of sensations that we arrive at beauty. To talk of a beautiful sound, such as a single note of a musical instrument, would be absurd; it is only a combination of sounds that can be called beautiful. The terms "beautiful smell," "beautiful taste," would cause the most ignorant to smile, though it may be contended that a dish uniting various flavours, or a perfume composed of well-assorted scents might be called beautiful. We look at the spectrum thrown on a screen, and say it is beautiful, but it is the effect of the various colours seen in juxtaposition, and the exquisite shading and melting of one into the other that we admire. When we speak of the beautiful colours of sunset, we forget that a fine sunset is in fact a grand chromatic display. We see the fiery red of the fleecy clouds and the deep blue of the sky contrasted with the green of the foliage, and the brown of the tree stems, followed by a flood of yellow light on a cool grey ground in the heavens, while the gloom of night is settling over the earth beneath, and the eye is pleased and satisfied. Were we to see the sun like a ball of red-hot iron set through a coppery sky over a sea of blood washing a coast line of red rocks overgrown with red seaweed, it is certain we should not speak of the beautiful colours of sunset. Let any one, to test what I maintain, look at any colour, however brilliant and pure, through a tube blackened inside, and say whether it appears beautiful. It is the great activity of the eye, which during our waking hours is constantly roaming from object to object, seldom seeing the same thing nor the same colour for more than a few consecutive moments that deceives us.

3. Much of the confusion as regards the names of colours arises, as it has doubtless at all times arisen, from the habit, difficult to explain, of using inexact designations, and even applying names to colours which we know to be incorrect. Poets, for instance, call gold red, though it is always yellow. We speak of white wines and red wines, though in reality, as we are well aware, they are yellow and purple, so that in a thousand years hence it may be possible for a literary man to say that we were colour-blind, our eyes having not yet acquired the capacity to see yellow and blue, yellow appearing to us colourless and purple red, and he may in support

of this assertion quote the line of a distinguished poet now living who speaks of the "costly *scarlet* wine," a term which is still more precise and emphatic than simple red. In the course of an investigation, undertaken a short time ago with another chemist, I found that my collaborateur and myself never exactly agreed as to the names to be given to the colours we saw. The series which he named blue, violet, purple, crimson, red, orange, I called violet, purple, crimson, red, orange, yellow, *i.e.*, what was to his eye blue was to mine violet; his violet was my purple, and so on. There was no reason to suppose that our perception of colour differed, the difference was in my opinion simply one of terms.

The writings of ancient authors abound with instances of the use of colour names which are seemingly incorrect. We find in Horace (Book IV., Ode 1) the lines:

> Tempestivius in domum
> Paulli, *purpureis* ales oloribus
> Comiss abere Maximi,
> Si torrere jecur quæris idoneum.

Another author says:

> *Purpurea* sub nive terra latet
> Brachia *purpurea* candidiora nive.

We are told by scholars that in these cases *purpuereus* means bright, shining, but it still remains to be explained why a word, which generally denotes a positive colour, whatever that colour may have been, comes in a few instances to be applied to white objects such as swans and snow. Of course the definition of a word may be so extended as to include any number of widely different meanings some of these meanings being perhaps due to its mistaken use by authors. It would probably not be difficult to find passages in modern authors in which the word blue sometimes means green, sometimes violet. I met with a case in point recently on reading again Goethe's delightful autobiography "Wahrheit und Dichtung." The author, when a young man, was skating on the river on a bitterly cold winter's day. "I had been on the ice," says he, "since early morning, and was therefore, when my mother later in the day drove up to admire the scene, being only lightly clad, almost frozen. She sat in her carriage wrapped in a *red* velvet fur mantle, which, held together in front with thick gold lace and tassels, looked magnificent. 'Give me, dear mother, your fur cloak,' said I without much consideration, 'I am fearfully cold.' She, too, did not consider long, and the next moment I had put on the cloak, which reaching nearly to my feet, being of a *purple* colour, trimmed with sable and ornamented with gold, suited very well the brown fur cap which I wore." Here it is evident that Goethe calls the same object first red, then purple, and yet Goethe was not colour-blind; he wrote, as every one knows, a work on the theory of colours.

4. Part of the vagueness and uncertainty attending the terminology of colour may be ascribed to a tendency we are all more or less liable to, that of describing colours in figurative and metaphorical terms. The habit, no doubt, arises from the pleasure we feel in comparing two objects, both of which are agreeable to the sense of sight. We speak of a girl having sky-blue eyes and cherry-red lips, whereas slate-coloured and brick-red would be more correct. How often we hear the expression, "he turned as white as a sheet," whereas the human skin is never under any circumstances, even after death, as white as a sheet. To say "he turned of a dirty yellowish-white," would be nearer the truth, though the expression might be thought somewhat inelegant. Poets and others speak of golden hair and silvery locks, but human hair though it may be bright, glistening, and so on, never reflects light in the manner peculiar to metals. Numerous examples of the same kind will occur to everyone. If, therefore, we meet in ancient authors with expressions relating to colour which seem exaggerated and

out of place, we must make some allowance for the tendency shown by men at all times to compare one beautiful object with another beautiful object, or one terrific object with another terrific object, without regard to exact literal truth. Generally speaking, I think we may safely say that no terms denoting colour, wherever met with, are to be considered strictly correct and appropriate unless they are referred to some fixed and known standard. The errors due to actual colour blindness need hardly, I think, be taken into consideration, since the hues which the colour blind are unable to distinguish lie so far apart as to make it difficult for any one with normal eyes to conceive the possibility of so great a defect.

The brilliant tints exhibited by the decaying foliage of the trees in this neighbourhood in the course of the autumn, forming a chromatic display such as those living near manufacturing towns have few opportunities of witnessing, have led me to think a little on the cause of the formation of these colours and its possible connection with chlorophyll, on the chemistry of which I have lately been making some experiments.

The colour of the leaves of plants is a phenomenon which is probably never quite stationary at any period of their development. When lying rolled up in the leaf bud they are like underground shoots and other parts of plants that have not been exposed to light, almost white; nevertheless they already contain a colouring matter called *etiolin*, the alcoholic solution of which is yellow and shows absorption bands similar to those of chlorophyll. Whether this etiolin on the leaf unfolding passes over into chlorophyll and whether it continues to be formed during the further stages of development is not known. All we know is that when the leaf expands it immediately becomes green from the formation of chlorophyll. It is, however, evident that more than one colouring matter is formed after exposure of the leaves of plants to light. The colour due to chlorophyll alone is probably seen in its purest state in the tender exquisite green of the young beech leaf or blade of corn. Other leaves, such as those of the oak, before attaining maturity have a decidedly yellow tinge, due it is supposed to the presence of an unusual proportion of phylloxanthin, the yellow colouring matter always accompanying chlorophyll. Indeed, the lively contrast of tints seen in the foliage of the woods in early spring, the yellowish hue of the oak, and the pure green of the beech and larch relieving the sombre colour of the fir tree and the yew, affords one of the most pleasing sights of that delightful season. In early summer the young shoots of some trees, such as the oak, the sycamore, and the thorn, as well as the young leaves near the summit of each shoot, are tinged of a lively red, passing by degrees into the green of the mature leaves. The fruit wings of the sycamore are for many weeks in the summer similarly tinted, and the effect of the pink blush gradually shading off into the pale green of the wing tips is one that painters might introduce with advantage into their pictures of still life. This red colour is said to be due to erythrophyll, the colouring matter formed in some leaves in the autumn, but whether the substance is in both cases really the same may be doubted. At the height of summer the foliage of trees displays a uniform green tint of varying depth, but it is probable that at this season the chlorophyll has already undergone a change, and I suspect that the sombre green of some leaves, such as those of the elm, in summer, is partly due to a product of decomposition called "modified chlorophyll," which yields solutions of a much less lively colour than the chlorophyll from which it is formed.

The summer stage is succeeded by that of the autumnal fading of foliage, a change so often observed that it needs no description. With the exaggeration so often employed when coloured objects are referred to, people frequently speak of the multitudinous tints of autumn. In reality, however, these colours, not counting the original green, are only four in number, viz., yellow, brown, red, and purple, and of these the last is a dull inconspicuous colour, while the red occurs so seldom in our native trees as to add but little to the total effect when our woods and plantations appear in their autumnal clothing. It is to the passing of the original green into yellow, and from yellow into brown, and the various shades and tintings so produced that the effect is in the main due. The yellow coloration is most distinctly seen in the chestnut and the elm. In the latter the gradual tinging of the deep green with yellow produces a peculiarly beautiful effect, and when the change is complete, and the whole tree (to use one of those figurative expressions to which one is so prone) is arrayed in a garb of gold, the appearance when first seen is almost startling. Arrived at this stage the leaves mostly fall, but retain their yellow hue for a short time only, the colour under the influence of air and moisture rapidly becoming brown, though they remain yellow if quickly dried. The oak and the beech keep their leaves after the yellow stage is passed, and the rich reddish-brown they then exhibit forms a distinct feature in the autumnal landscape. Young beech trees, as every one knows, remain clothed with brown leaves during the winter, and only lose them on the unfolding of the fresh leaves in spring.

The leaves of some of our native plants, such as the wild cherry, the currant, the bramble, and various species of sorrel, turn of a lively red in autumn, but this coloration intensified to a positive scarlet is more distinctly seen in some of the exotics which have been introduced into our gardens, such as the Virginia creeper and the Azalea. A mixture of red and yellow is rarely observed on the same leaf. It is a singular circumstance that the leaves of the oak and sycamore, the young shoots of which are so often tinged of a lively red, do not turn red in fading, but yellow, from which it may be inferred that the process of decay in leaves does not lead back to the same stage at which that of development commenced.

The autumnal purple coloration of leaves is met with in a few native plants, notably the bryony, the privet, and the dogwood. It imparts a dingy hue to the leaves, and is therefore not much noticed. I observed a case of its occurrence last summer, which I had not previously seen mentioned. Passing through a field of corn, which was then nearly ripe, I saw a number of plants by the sides of the path with blades distinctly purple. On closer observation it was evident that in all cases where this coloration occurred the ears of corn had been cut off before ripening, the act probably of idle passers-by, those plants which remained uninjured having become yellow as usual. I inferred that it was the injury sustained by the plant, and the arrest of its main function, that of the development of seed, that had led to the formation of some purple substance, not seen during the process of natural decay. I made some experiments on this purple colouring matter, but all I can say about it is, that it belongs to the same class as the red and yellow colouring matters of faded leaves. I anticipated the possibility of its being identical with a product of the decomposition of chlorophyll, crystallising in purple needles, which I had discovered in the course of my investigation, but I was disappointed in my expectation.

As regards the nature of the colouring matters to which the various colours of faded leaves are due, opinions vary. It is generally supposed that they are formed from chlorophyll by some process of decomposition, probably of oxidation, and nothing can be more natural than this supposition. On exposure of the leaf to light and air, after its vital functions have ceased, the green colour due to chlorophyll gradually disappears and is succeeded by red, yellow, or purple. Therefore, it is argued, the respective colouring matters must be derivatives of chlorophyll. Nevertheless, this view is open to some objection. As regards, in the first place, the red colouring matter, since no one has succeeded in obtaining it artificially, it must be formed, if a derivative of chlorophyll, by some process not purely chemical. I have, indeed, obtained as one of the products of decomposition of chlorophyll a substance crystallising in red laminæ, having a semi-metallic appearance by reflected light, but this substance is entirely distinct from the red colouring matter of faded leaves. The latter may easily be procured, at least in an impure state, by extracting the reddened leaves of the garden Azalea or the Virginia Creeper with boiling spirits of wine, evaporating the extract at a gentle heat, and treating the residue with water, in which the colouring matter dissolves. The solution has a fine crimson colour like that of red ink. The colour does not change on the addition of such acids as exert no oxidising action. Nitric acid gradually turns it yellow. By the addition of alkalies, such as ammonia, its colour changes to a yellowish-green, and it has then very much the appearance of an alcoholic solution of chlorophyll, but it does not show either before or after the addition of alkali the least indication of absorption bands, merely a general darkening of the more refrangible end of the spectrum. With lead acetate it gives a grass-green precipitate. These reactions show that the colouring matter belongs to the same class as that of the rose and red flowers generally; but in the present state of our knowledge regarding this class of substances, it is quite impossible to say whether any two members belonging to the series are identical or not. One thing, however, is certain, viz., that the red colouring matter of faded leaves is actually formed during the process of decay; it does not pre-exist in the green leaf, though there can be no doubt that leaves which are naturally more or less red, such as those of the copper beech and various species of colium, contain a ready formed red colouring matter.

As to the yellow colouring matter of faded leaves, whether it pre-exists in the green leaf or is formed from chlorophyll or some other leaf constituent, it is not so easy to pronounce a decided opinion. This colouring matter, called by Berzelius *xanthophyll,* is supposed by some to be identical with phylloxanthin, the yellow substance which, according to Fremy and others, always accompanies the chlorophyll of green leaves. Of its properties little is known, and that little I find to be more or less incorrect. It is said to be soluble in alcohol and ether, insoluble in water, to turn green with acids, and to show a peculiar absorption spectrum different to that of chlorophyll. These statements require correction. It is, in fact, soluble in water, but insoluble in ether; it does not turn green with acids,, and the absorption bands which it shows are due to an admixture of chlorophyll, as a few simple experiments are sufficient to show. Having taken some bright yellow elm leaves I extracted them with boiling spirits of wine, and obtained a greenish-yellow liquid, which, after filtration, showed only the dark absorption band in the red corresponding to band I. of the chlorophyll spectrum. I evaporated the extract in the water bath, and during evaporation observed a deposit form on the sides of the dish consisting of green fat-like masses. On adding water to the residue a portion dissolved yielding a golden-yellow liquid, while the fat-like masses remained undissolved. After pouring off the liquid and washing the residue with water, the latter was dissolved in hot alcohol, when it gave a yellowish-green liquid which showed all the absorbtion bands of chlorophyll distinctly. The golden-yellow watery solution on the other hand showed no trace of absorbtion bands, merely a general darkening of the blue end of the spectrum. Its colour was evidently due to a yellow colouring matter contained in it. It gave an abundant yellow precipitate with lead acetate, and a dark green precipitate with ferric chloride. It also contained a considerable quantity of tannin, since it yielded a thick curdy precipitate with gelatine and an abundant deposit on the addition of a mineral acid. On again evaporating the solution in the water bath some decomposition evidently took place, for on adding water to the residue a quantity of matter in the form of brown powder remained undissolved. It is almost certain that it is the same process of decomposition going on in the yellow leaf on exposure to air and moisture that causes the colour to change to brown. I think it probable that the process is one of oxidation, and that it affects the tannin of the leaf or the solution rather than the yellow colouring matter, for it is well known that watery solutions of tannin undergo decomposition, accompanied by change of colour from light to dark, on exposure to air, especially when the solutions are hot. This simple experiment shows that the yellow colour of faded elm leaves is due partly, perhaps chiefly, to a yellow colouring matter soluble in water, partly to a yellowish green substance consisting essentially of chlorophyll. The former is, in my opinion, the true xanthophyll.

In order to gain, if possible, a little more insight into the process whereby the colour of green leaves changes to yellow, I took an alcoholic extract of fresh grass, which was of the usual bright green colour, and exposed it in a window to the action of the sun and air. After some days' exposure it had undergone the well known and frequently described transformation, *i.e.* the bright green colour had changed to a greenish-yellow and the solution from being opaque even in thin layers had become transparent in consequence of the oxidation of the chlorophyll contained in it. Now this liquid, though not quite so yellow as the alcoholic extract of faded elm leaves, was found closely to resemble the latter. On evaporating over the water bath and adding water to the residue a yellow liquid was obtained, containing a colouring matter, the reactions of which were similar to those of the substance from elm leaves. No tannin, however, could be detected in the solution and this may serve to explain the fact that blades of grass, corn, &c., do not ultimately become brown in fading, but remain yellow. The portion of the residue after evaporation left undissolved by water, was green and fatty, and its solution in alcohol showed the absorption bands due to modified chlorophyll.

These experiments leave the question of the nature and mode of formation of xanthophyll undecided. It may be one and the same substance in all leaves, or it may differ according to the source whence it is derived, it may be formed by the oxidation of chlorophyll, or it may pre-exist in the green leaf. I am inclined to think that it exists ready formed in the green leaf, but is not then seen on account of the far greater tinctorial powers of the chlorophyll present at the same time, and that it makes its appearance only when the chlorophyll has been decomposed, the sole trace left by the latter being the slight greenish tinge which all faded yellow leaves show more or less. The varying proportion of xanthophyll contained in green leaves would explain the fact, difficult to understand if we suppose it to be derived from chlorophyll, that some leaves assume a deep yellow colour in fading, while others remain of a pale yellow, and others again are almost colourless when they fall.

I will now conclude, hoping, if I have not communicated anything strikingly new, that I may at least have succeeded in affording the meeting a few moments' amusement.

Bromley, Kent,
10th December, 1881.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

December 5th, 1881.

ALFRED BROTHERS, F.R.A.S., President of the Section, in the Chair.

Professor A. MILNES MARSHALL exhibited specimens of the larval form of starfishes, echinoïds, holothurids, and crinoïds, and described briefly the various stages of development, commenting on the great differences between the larval forms and the adult in each case, and also on the great differences between the larvæ and closely allied groups. He considered this latter feature as indicating that the individual differences were acquired separately by each group, whilst the general resemblance in plan was due to inheritance, and represented the primitive ancestral forms.

The points of individual difference were in all cases ultimately absorbed, and formed no part of the adult animal.

The slides exhibited were prepared at the Zoological Station, exhibited at Naples by Dr. Dohrn.

Mr. R. ELLIS CUNLIFFE brought the 3rd vol. of the Challenger Expedition, for inspection by the members.

Mr. J. COSMO MELVILL exhibited Limnotrochus Kirkii (Edgar Smith), from Lake Tanganyika, which with the newly allied and also recently described L. Thomsoni of the same author, constitutes a new genus of Mollusca. He read a detailed description of the genus, and pointed out its chief characteristics, which were the trochoïd shape, deep umbilicus, and quadrangular aperture, likewise calling attention to the unusual ornamentation of the whorls, which were remarkable in a fresh water genus. Mr. Smith, from the similarity of the operculum, which is horny and few whorled, places the genus amongst the Littorinidæ and near the genus Echinella and Risella, which it resembles in configuration. It is, of course, impossible to ascertain actually the position of the genus until the animal has been examined, but judging from the shell alone, Mr. Melvill considered it more approached the genus Solarium—§ Philippia, agreeing with that in the ornamented edge of the whorls, and in the deep umbilicus, which latter is wanting throughout the whole of the Littorinidæ; with the exception of the genus Echinella. The operculum of Limnotrochus is certainly Littorinoïd.

He also exhibited a shell of even greater interest, recently discovered by Prof. Morelet, as a new genus, Cyclosurus, from the Mayotte or Mayotta Islands, about 300 miles N.W. of Madagascar, at the northern entrance to the Mozambique Channel.

This land mollusc Cyclosurus, Mariei, (Morclet) was recently discovered there, but few specimens have hitherto found their way to Europe, and, although closely allied to the genus Cyclophorus, the shell bears more resemblance to a Dentalium, being altogether evolute with the exception of the first two very small whorls, after which it projects straight like a horn.

It is also conspicuous for being very minutely ribbed longitudinally, each rib bearing a quantity of very minute rough spines.

It was suggested by Mr. Rogers that it might be a monstrosity, but this can hardly be the case, as if a monstrosity, it is that of an undescribed species, the texture being dissimilar from any known shell, and, besides; all the specimens that have been discovered are of a similar evolute formation.

Ordinary Meeting, January 10th, 1882.

J. P. Joule, D.C.L., LL.D., F.R.S, &c., in the Chair.

"On Differential Resolvents, and Partial Differential Resolvents," by Robert Rawson, Esq., Assoc. I.N.A., Hon. Member of the Society.

Arts. 1 to 8 contain the first and second differential resolvents of a cubic, using therein one independent variable only—and, from the second differential resolvent the usual root of the cubic is determined.

In Arts. 9 to 11 there is the first partial differential resolvents of a general cubic, using therein two independent variables—and, from this partial differential resolvent the root of the general cubic is obtained.

Arts. 12 to 14 contain the first partial differential resolvents of a quartic, using therein three independent variables—and, from this resolvent the root of the quartic is determined.

1. Let $y^3 + ay + m = 0$ ....(1)

be a cubic in which (a) and (m) are functions of x, a variable parameter.

For convenience, $y^1 = \frac{dy}{dx}$, $a^1 = \frac{da}{dx}$ &c., will be used.

Differentiate (1) with respect to x, then

$$y^1 = -\frac{a^1 y + m^1}{3y^2 + a} = \mathrm{P}y^2 + \mathrm{Q}y + \mathrm{R} \quad \ldots\ldots\ldots\ldots (2)$$

where P, Q, R are functions of (a, m) to be determined as follows:—

$$-a^1 y - m^1 = 3\mathrm{P}y^4 + 3\mathrm{Q}y^3 + (3\mathrm{R} + a\mathrm{P})y^2 + a\mathrm{Q}y + a\mathrm{R}$$

Eliminate from this equation y^4 and y^3 by means of the cubic (1), then

$$-a^1y-m^1=3\mathrm{P}(-ay^2-my)+3\mathrm{Q}(-ay-m)$$
$$+(3\mathrm{R}+a\mathrm{P})y^2+a\mathrm{Q}y+a\mathrm{R}$$

or,

$$(3\mathrm{R}-2a\mathrm{P})y^2+(a^1-3m\mathrm{P}-2a\mathrm{Q})y+m^1+a\mathrm{R}-3m\mathrm{Q}=0$$

To satisfy this equation it is necessary and sufficient that

$$3\mathrm{R}-2a\mathrm{P}=0 \text{ ....(3)}$$
$$a^1-3m\mathrm{P}-2a\mathrm{Q}=0\text{...... ....(4)}$$
$$m^1+a\mathrm{R}-3m\mathrm{Q}=0\text{........................(5)}$$

From these equations the values of P, Q, R are readily found to be

$$\mathrm{P}(4a^3+27m^2)=9ma^1-6am^1$$
$$\mathrm{Q}(4a^3+27m^2)=2a^2a^1+9mm^1$$
$$\mathrm{R}(4a^3+27m^2)=6ama^1-4a^2m^1$$
$$\therefore 3\mathrm{R}=2a\mathrm{P}$$

Substitute these values in (2), then

$$y^1=\frac{9ma^1-6am^1}{4a^3+27m^2}\cdot y^2+\frac{2a^2a^1+9mm^1}{4a^3+27m^2}\cdot y+\frac{6ama^1-4a^2m^1}{4a^3+27m^2} \quad (6)$$

Equation (6) is, therefore, the first differential resolvent of the cubic (1).

Hence the cubic (1) is the integral of (6), and the value of y which satisfies (6) is, then, a root of the cubic (1).

2. To find the second differential resolvent of the cubic (1) it will be convenient to write (6) as follows:—

$$y^1+py^2-\mathrm{Q}y+\frac{2ap}{3}=0\text{........................(7)}$$

where, $\qquad (4a^3+27m^2)p=6am^1-9ma^1$

Differentiate (7) with respect to x, then

$$y^{11}+2pyy^1+p^1y^2-\mathrm{Q}y^1-\mathrm{Q}^1y+\frac{2a^1p}{3}+\frac{2ap^1}{3}=0 \text{ ...... (8)}$$

From (7) there results

$$yy^1=\mathrm{Q}y^2-py^3-\frac{2apy}{3}$$

$$=\mathrm{Q}y^2+\frac{apy}{3}+mp$$

Substitute this value in (8), then

$$y^{11} + \left(2Q + \frac{p^1}{p}\right)py^2 + \left(\frac{2ap^2}{3} - Q^1\right)y - Qy^1 + \frac{2ap^1}{3} + \frac{2a^1p}{3}$$
$$+ 2mp^2 = 0 \quad \text{..........................(9)}$$

From (7) we obtain

$$py^2 = Qy - \frac{3ap}{3} - y^1$$

Then (9) becomes

$$y^{11} - \left(3Q + \frac{p^1}{p}\right)y^1 + \left(\frac{2ap^2}{3} + \frac{Qp^1}{p} + 2Q^2 - Q^1\right)y + 2mp^2$$
$$- \frac{4apQ}{3} + \frac{2pa^1}{3} = 0 \quad \text{....................(10)}$$

But, $$2mp^2 - \frac{4apQ}{3} + \frac{2pa^1}{3} = \frac{2p}{3}(3mp - 2aQ + a^1) = 0$$

Then (10) may be written

$$y^{11} - \left(3Q + \frac{p^1}{p}\right)y^1 + \left(\frac{2ap^2}{3} + Q\frac{p^1}{p} + 2Q^2 - Q^1\right)y = 0 \quad \text{...(11)}$$

Restore the values of p and Q, then

$$\frac{d^2y}{dx^2} - \left\{\frac{d}{dx}\log\frac{3ma^1 - 2am^1}{\sqrt{4a^3 + 27m^2}}\right\}\frac{dy}{dx} + \left\{\frac{a^1m^{11} - m^1a^{11}}{2am^1 - 3ma^1}\right.$$
$$\left. + \frac{6am(a^1)^3 - 6a(m^1)^3 - 6a^2m^1(a^1)^2}{(2am^1 - 3ma^1)(4a^3 + 27m^2)}\right\}y = 0 \quad \text{.........(12)}$$

Equation (12) is, therefore, the second differential resolvent of the cubic (1). The value of y which satisfies (12) is a root of the cubic (1), and, either of the three roots of the cubic (1) is a particular solution of the differential equation (12).

3. When (a) is constant, then, the first and second differential resolvents respectively become

$$\frac{4a^3 + 27m^2}{6am^1} \cdot \frac{dy}{dx} + y^2 - \frac{3m}{2a} \cdot y + \frac{2a}{3} = 0 \quad \text{...........(13)}$$

$$\frac{d^2y}{dx^2} - \left\{\frac{d}{dx}\log.\left(\frac{-2am^1}{\sqrt{4a^3 + 27m^2}}\right)\right\}\frac{dy}{dx} - \frac{3(m^1)^2}{4a^3 + 27m^2} \cdot y = 0 \quad \text{.......(14)}$$

4. If (m) be such as to satisfy

$$\frac{m^1}{\frac{4a^3}{27} + m^2} = 1 \quad \text{....................................(15)}$$

then the coefficient of $\frac{dy}{dx}$ in (14) is zero, and it becomes

$$\frac{d^2y}{dx^2} - \frac{y}{9} = 0 \quad \text{......(16)}$$

The general solution of (16) is well known to be

$$y = (c_1\epsilon^x)^{\frac{1}{3}} + (c_2\epsilon^{-x})^{\frac{1}{3}} \quad \text{......(17)}$$

wher c_1, c_2 are arbitrary constants to be determined. Integrate (15) with respect to x, then,

$$m = \frac{\epsilon^x}{2} - \frac{2a^3}{27}\epsilon^{-x} \quad \text{......(18)}$$

Hence, equation (17) is a root of the cubic

$$y^3 + ay + \frac{\epsilon^x}{2} - \frac{2a^3}{27}\epsilon^{-x} = 0 \quad \text{......(19)}$$

The values of c_1, c_2 are readily determined by substituting the value of y in (17) in (19), they are as follows:

$$c_1 = -\tfrac{1}{2}$$

$$c_2 = \frac{2a^3}{27}$$

Substitute these values in (17), then

$$y = \frac{a}{3}\left(2\epsilon^{-x}\right)^{\frac{1}{3}} - \left(\frac{\epsilon^x}{2}\right)^{\frac{1}{3}} \quad \text{......(20)}$$

is a root of the cubic (19).

(5) The values of ϵ^x, ϵ^- in (19) can be determined by means of a quadratic, so as to satisfy the classical cubic

$$y^3 + ay + b = 0 \quad \text{......(21)}$$

This equation will coincide with (20) if

$$b = \frac{\epsilon^x}{2} - \frac{2a^3}{27}\epsilon^{-x} \quad \text{......(22)}$$

Then, $$\epsilon^x = b - \sqrt{b^2 + \frac{4a^3}{27}}$$

And, $$\frac{2a^3}{27}\epsilon^{-x} = -\left(\frac{b}{2} + \frac{1}{2}\sqrt{b^2 + \frac{4a^3}{27}}\right)$$

Therefore,

$$y = \left\{-\frac{b}{2} + \frac{1}{2}\sqrt{b^2 + \frac{4a^3}{27}}\right\}^{\frac{1}{3}} - \left\{\frac{b}{2} + \frac{1}{2}\sqrt{b^3 + \frac{4a^3}{27}}\right\}^{\frac{1}{3}} \quad \text{....(23)}$$

The value of y in (23) agrees with Cardan's formula.

The process of obtaining the first and second differential resolvents is a direct process, and it is only fair to state that it has been gathered entirely from the correspondence with Sir James Cockle, F.R.S., &c., and the Rev. Robert Harley, F.R.S., &c.; with whom originated the important invention of differential resolvents of algebraical equations.

I am not sure whether the results in Arts. (4) and (5) have been published by either Sir James Cockle or Rev. Robert Harley.

It is more than curious that Cardan's formula should be reached as it has been, without the slightest assumption, by means of the second differential resolvent. And, the method which has been adopted is, in my opinion, very suggestive in the theory of higher algebraical equations. Especially so when several independent variables are made use of.

6. If in (14) we put

$$\frac{-2am^1}{\sqrt{4a^3+27m^2}}=\frac{2ar}{\sqrt{27}} \quad \text{......................}(24)$$

where (r) is another function of x.

Then,
$$\frac{(m^1)^2}{4a^3+27m^2}=\frac{r^2}{27}$$

Hence, there results by substitution

$$\frac{d^2y}{dx^2}-\frac{dr}{rdx}\cdot\frac{dy}{dx}-\frac{r^2}{9}\cdot y=0 \quad \text{......................}(25)$$

which is the second differential resolvent of the cubic

$$y^3+ay+\frac{\varepsilon^{-\int rdx}}{2}-\frac{2a^3}{27}\epsilon^{\int rdx} \quad \text{......................}(26)$$

The value of (m) is found by integrating (24), and, solving algebraically with respect to (m), to be

$$m=\frac{1}{2}\epsilon^{-\int rdx}-\frac{2a^3}{27}\epsilon^{\int rdx} \text{..........................}(27)$$

7. If y and z are such as to satisfy the equation

$$\frac{dy}{ydx}=\beta z+\frac{dr}{2rdx} \quad \text{........... ....}(28)$$

Substitute this value of y in terms of z in (25), and it becomes

$$\frac{dz}{dx}+\beta z^2=\frac{1}{4\beta}\left\{-2\frac{d}{dx}\left(\frac{dr}{rdx}\right)+\left(\frac{dr}{rdx}\right)^2+\frac{4r^2}{9}\right\} \quad \text{......}(29)$$

An equation which is soluble by means of (26) and (28) for all values of the function r.

8. Put, $r = Ax^{2n}$, where (A) is constant, then

$$\frac{dz}{dx} + \beta z^2 = \frac{n(n+1)}{\beta x^2} + \frac{A^2}{9\beta}x^{4n} \quad \text{..............(30)}$$

which is soluble by means of (31) and (32)

$$\frac{dy}{ydx} + \beta z + \frac{n}{x} \quad \text{...... ....(31)}$$

$$y^3 + ay + \frac{1}{2}\epsilon^{-\frac{Ax^{2n+1}}{2n+1}} - \frac{2a^3}{27}\epsilon^{\frac{Ax^{2n+1}}{2n+1}} = 0 \quad \text{...............(32)}$$

Equation (30) coincides with the Riccatian form in one case only, viz., when the exponent of x is zero.

This property vanquished all hopes of connecting the solution of Riccati's equation with the roots of a cubic in its present form. This result was communicated to Sir James Cockle, who kindly sent me the following neat solution of (30).

Assume the Riccatian

$$\frac{du}{dt} + w^2 = 1$$

Change the independent and dependent variables t and u, for x and z, by the equations

$$3(2n+1)t = A^{\frac{1}{2}}x^{2n+1}$$

$$3\beta z = A^{\frac{1}{2}}x^{2n}w - \frac{3n}{x}$$

Then the above Riccatian on reduction coincides with (30).

The solution of a general cubic by a partial differential resolvent with two independent variables.

9. Let $V^3 + 3aV^2 + 3RV + 3S = 0$ ....(33)

be a general cubic where (a) is constant and R, S functions of x, y.

Differentiate (33) with respect to x, y respectively, then

$$(V^2 + 2aV + R)\frac{dV}{dx} + \frac{dR}{dx}\cdot V + \frac{dS}{dx} = 0 \quad \text{..........(34)}$$

$$(V^2 + 2aV + R)\frac{dV}{dy} + \frac{dR}{dy}\cdot V + \frac{dS}{dy} = 0 \quad \text{..........(35)}$$

From these two equations it follows that

$$\left(\frac{dR}{dy}\cdot V+\frac{dS}{dy}\right)\frac{dV}{dx}=\left(\frac{dR}{dx}\cdot V+\frac{dS}{dx}\right)\frac{dV}{dy}\text{..........}(36)$$

Equation (34), which is a partial differential equation, is the *first partial differential resolvent* of the cubic (33) together with the conditional equation (36).

Hence it follows that the value of V, which satisfies (34), and satisfies also, the conditional equation (36), is a root of the cubic (33); and, each of the roots of the cubic (33) is a solution of the partial differential equations (34), (35), and (36).

10. Since R, S are arbitrary functions of x, y, it remains to determine them so as to satisfy the equations (34), (35), and (36), when

$$V=x+y+\alpha\text{ ....}(37)$$

where α, is a constant quantity.

Substitute V as given in (37) in (36), then

$$\left(\frac{dR}{dy}-\frac{dR}{dx}\right)(x+y+\alpha)+\frac{dS}{dy}-\frac{dS}{dx}=0\text{ ....}(38)$$

Now, if the first term of (38) is a quadratic in terms of x, y, then, the second term must be a quadratic also. This readily suggests the following equation, viz.

$$\frac{dR}{dy}-\frac{dR}{dx}=\beta(x-y)\text{........................}(39)$$

Substitute this value in (38), and it becomes

$$\frac{dS}{dy}-\frac{dS}{dx}=\beta y^2-\beta x^2+\alpha\beta y-\alpha\beta x\text{..............}(40)$$

The integrals of (39) and (40), are

$$R=\beta xy+C\text{..........................}(41)$$

$$3S=\beta y^3+\beta x^3-3\alpha\beta xy+3C_1\text{.................}(42)$$

where C, C_1 are independent of x and y.

The values of β, α, C are determined from (34), and are as follows, $\alpha=-a$; $\beta=-1$, and $C=a^2$.

The constant $3C_1=a^3$ is found by substituting V, R, S in the cubic (33). Hence,

$$V=x+y-a\text{.......................}(43)$$

is a root of the general cubic.

$$V^3+3aV^2+3(a^2-xy)V-x^3-y^3-3axy+a^3=0 \ldots\ldots \quad (44)$$

The remaining two roots must be obtained from

$$V^2+(x+y+2a)V+x^2+y^2-xy+ax+ay+a^2=0 \ldots\ldots (45)$$

11. The values of x, y in (44) can be found by a quadratic so as to make (44) coincide with the classical cubic.

$$V^3+3aV^2+3bV+c=0 \ldots\ldots (46)$$

For this purpose the equations

$$a^2-xy=b \ldots\ldots (47)$$

$$x^3+y^3+3axy=a^3-c \ldots\ldots (48)$$

will be necessary.

From these two equations there results

$$x^3=\frac{3ab-2a^3-c}{2}+\frac{1}{2}\sqrt{(3ab-2a^3-c)^2-4(a^2-b)^3}$$

$$y^3=\frac{3ab-2a^3-c}{2}-\frac{1}{2}\sqrt{(3ab-2a^3-c)^2-4(a^2-b)^3}$$

The solution of a quartic by a partial differential resolvent with three independent variables.

12. Let

$$V^4+tV^2+RV+S=0 \ldots\ldots (49)$$

be a quartic in which t, R, S are functions of the three variables x, y, z.

Differentiate (49) with respect to x, y, z respectively, then

$$(4V^2+2tV+R)\frac{dV}{dx}+\frac{dt}{dx}\cdot V^2+\frac{dR}{dx}\cdot V+\frac{dS}{dx}=0 \ \ldots\ldots (50)$$

$$(4V^2+2tV+R)\frac{dV}{dy}+\frac{dt}{dy}\cdot V^2+\frac{dR}{dy}\cdot V+\frac{dS}{dy}=0 \ \ldots\ldots (51)$$

$$(4V^2+2tV+R)\frac{dV}{dz}+\frac{dt}{dz}\cdot V^2+\frac{dR}{dz}\cdot V+\frac{dS}{dz}=0 \ \ldots\ldots (52)$$

From (50) and (51); from (51) and (52) there results

$$\left(\frac{dt}{dy}\cdot V^2+\frac{dR}{dy}\cdot V+\frac{dS}{dy}\right)\frac{dV}{dx}=\left(\frac{dt}{dx}\cdot V^2+\frac{dR}{dx}\cdot V+\frac{dS}{dx}\right)\frac{dV}{dy} \ldots\ldots (53)$$

$$\left(\frac{dt}{dy}\cdot V^2+\frac{dR}{dy}\cdot V+\frac{dS}{dy}\right)\frac{dV}{dz}=\left(\frac{dt}{dz}\cdot V^2+\frac{dR}{dz}\cdot V+\frac{dS}{dz}\right)\frac{dV}{dy} \ldots\ldots (54)$$

Equation (50) is the first partial differential resolvent of the quartic (49) together with the two conditional equations (53) and (54).

The value of V, in functions of x, y, z, which satisfies (50), and satisfies also the conditional equations (53), (54), is a root of the quartic (49), and a root of the quartic (49) is a solution of each of the equations 50 to 54.

13. With a view, therefore, to obtain a solution of (53), (54), it will be necessary to try a few simple assumptions of the forms of t, R, s, which are suggested by the equations themselves—

Put $\frac{dt}{dy}=1$; $\frac{dt}{dx}=1$; $\frac{d\mathrm{R}}{dy}-\frac{d\mathrm{R}}{dx}=0$ ....(55)

By integrating these equations, then

$$t=x+y+z_1 \qquad (56)$$

$$\mathrm{R}=(y-x)z_2 \qquad (57)$$

where z_1, z_2 are functions of z only.

The above assumption, viz. (55), necessarily implies that S is a function of x, y only, or, $\frac{d\mathrm{S}}{dz}=0$.

Substitute the above values in (53), (54), then

$$\left(\mathrm{V}^2+z_2\mathrm{V}+\frac{d\mathrm{S}}{dy}\right)\frac{d\mathrm{V}}{dx}=\left(\mathrm{V}^2-z_2\mathrm{V}+\frac{d\mathrm{S}}{dx}\right)\frac{d\mathrm{V}}{dy} \qquad (58)$$

$$\left(\mathrm{V}^2+z_2\mathrm{V}+\frac{d\mathrm{S}}{dy}\right)\frac{d\mathrm{V}}{dz}=\left(\frac{dz_1}{dz}\cdot\mathrm{V}^2+\frac{dz_2}{dz}(y-x)\mathrm{V}\right)\frac{d\mathrm{V}}{dy} \qquad (59)$$

If, then, the roots of the quartic (49) be such as to satisfy

$$\mathrm{V}^2+z_2\mathrm{V}+\frac{d\mathrm{S}}{dy}=0 \qquad (60)$$

$$\mathrm{V}^2-z_2\mathrm{V}+\frac{d\mathrm{S}}{dx}=0 \qquad (61)$$

These equations will satisfy (58), (59), providing

$$\frac{dz_1}{dz}=2z_2 \qquad (62)$$

$$\frac{d\mathrm{S}}{dy}-\frac{d\mathrm{S}}{dx}=\frac{dz_2}{dz}(y-x) \qquad (63)$$

Since S is a function of x, y only, then

$$\frac{dz_2}{dz}=-1 \text{ or, } z_2=-z$$

Integrating (62) (63), we have

$$z_1=-z^2$$

$$\mathrm{S}=xy$$

Substitute these values in (60), (61), then

$$V^2 - zV + x = 0 \dots\dots\dots\dots (64)$$

$$V^2 + zV + y = 0 \dots\dots\dots\dots (65)$$

$$\text{And,} \quad t = x + y - z^2$$

$$R = z(x - y)$$

14. The values of V in (64), (65), which satisfy (50) also, are the roots of the quartic

$$V^4 + (x + y - z^2)V^2 + z(x - y)V + xy = 0 \dots\dots\dots (66)$$

Equation (66) will coincide with the quartic

$$V^4 + aV^2 \pm bV + c = 0 \dots\dots\dots\dots (67)$$

If x, y, z are determined from

$$x + y - z^2 = a \dots\dots\dots\dots (68)$$

$$z(x - y) = \pm b \dots\dots\dots\dots (69)$$

$$xy - c \dots\dots\dots\dots (70)$$

These values depend upon the well known cubic

$$z^6 + 2az^4 + (a^2 - 4c)z^2 - b^2 - 0 \dots\dots\dots\dots (80)$$

See Todhunter's theory of Eqs., p. 112, 2nd ed.

Havant, Sept., 1881.

Postscript.—Equation (6) is made linear by the relation

$$y = \frac{4a^3 + 27m^2}{6am^1 - 9ma^1} \cdot \frac{dz}{zdx} \dots\dots\dots\dots (81)$$

which gives

$$\frac{d^2z}{dx^2} + \frac{d}{dx}\log\left(\frac{(4a^3 + 27m^2)^{\frac{5}{6}}}{2am^1 - 3ma^1}\right)\frac{dz}{dx} + 6a\left(\frac{2am^1 - 3ma^1}{4a^3 + 27m^2}\right)^2 z = 0 \dots (82)$$

General Meeting, January 24th, 1882.

R. ANGUS SMITH, Ph.D., F.R.S., &c., in the Chair.

Mr. William Thomas Arnold, B.A., was elected an Ordinary Member of the Society.

Ordinary Meeting, January 24th, 1882.

R. ANGUS SMITH, Ph.D., F.R.S., &c., in the Chair.

"On the British species of *Erythræa*," by CHARLES BAILEY, F.L.S.

I exhibit to-night a full set of the species of this polymorphic genus, from numerous localities in Great Britain, to show their great range of form and habit. Their numerous variations appear to depend upon the greater or lesser ramification of the stem, and of the inflorescence.

In *Erythræa pulchella*, Fries, we have the single-stemmed, one to three flowered form, an inch or an inch and a half in height, and at the other extreme we have a repeatedly-branched form which was at one time separated from *pulchella* as a distinct species, under the name of *E. ramosissima*, Pers. When the inflorescence is spicate it is the *E. tenuiflora*, Link; this form Mr. Townsend meets with near Cowes, Isle of Wight.

Perhaps the most variable species is the widely-distributed *E. Centaurium*, Pers., as the specimens exhibited will show. Its most usual form is that in which the stems, whether solitary or several springing from the crown of the root, branch in the upper third of their height, the branches terminating in one or more dense heads. A second form, less common than the first, bears numerous branches from the base to the summit, its terminal cymes having a spicate direction. A third form, which I meet with on the Lancashire coast sandhills, has a solitary slender stem terminated in its upper eighth by one to three few-flowered contracted cymes; the habitat in which it usually occurs is at the base of the sandhills at the edges of the flat damp hollows in which *Erythræa littoralis* is so abundant. It varies in height from 6 to 18 inches, and the leaves of the lower fourth of the stem are obtuse, obovate, and at times even spathulate. Its habit suggests its being a hybrid between *E. Centaurium* and *E. littoralis*; but its characters range with *E. Centaurium.* At the opposite extreme is a fourth form, also maritime, which is met with growing amongst the grass of exposed cliffs and sea-slopes. It is a stunted form with spreading capitate heads, whose breadth often exceeds the entire height of the plant. Its height is usually determined by that of the contiguous herbage, and when it can secure the shelter of tall plants its stem elongates and branches in the upper half. This form is the var. *capitata* of Koch, and the *pseudo-latifolia* of the London Catalogue. I have not observed it away from the western coast, although I have seen on Afton Downs, in the Isle of Wight, plants with more contracted and fewer-flowered heads, branching from the base, which must probably be referred to this form. I have collected var. *capitata* on cliffs near Porth Curnow, at the Land's End, Cornwall; in Holloways and Penally Burrows, Tenby, Pembrokeshire; and in Anglesey on the cliffs opposite the ruins of Langwfen church, Aberffraw, and on the steep grassy slopes at the foot of the cliffs above the South Stack Lighthouse, near Holyhead. The plants in this latter station are identical in habit with the single-headed specimens of E. *capitata*, W., referred to below; they grow less than an inch in height in the shape of little cushions for a considerable distance up the mountain side.

The rarest of our Erythræas is *E. latifolia*, Sm., a species which, I believe, does not occur out of England, and as far as is known is confined to the Lancashire coast. The three specimens exhibited are from Southport, North Shore (Liverpool), and Seaforth Common, but I am afraid that some of these stations are built upon. I have never been fortunate enough to find it, but it might reward a careful search on the coast from Ainsdale in the direction of Liverpool.

Erythræa littoralis, Fries, is the least variable of our British species; its narrow spathulate leaves, strict habit, and the peculiar orange colour of the stem and leaves in autumn render it easy of detection. It is extremely plentiful on the Lancashire coast south of Birkdale.

A well-marked species of *Erythræa*, new to the British Flora, was detected by Mr. Frederick Townsend, M.A., F.L.S., about two years ago, and the specimens now exhibited I collected in July last, in the stations indicated by its discoverer, viz: on Afton and Compton Downs, Freshwater, Isle of Wight. It differs from all the other British species in possessing free anthers, the filaments springing from the base of the corolla, instead of from the throat as in all the other forms. This species is the *E. capitata,* Willd. var. *sphærocephala,* Towns., as described in the Journal of Botany for November, 1879, p. 327; March, 1881, p. 87; and October, 1881, p. 302; also in the Journal of the Linnean Society, Bot., Vol. XVIII., p. 398. Like the other species of this genus there are two extreme forms; a luxuriant form in which secondary axillary stalked heads arise from the outer bracts of the primary head which they overtop; and a dwarf form in which the axillary heads are absent. The multi-capitate form occurs plentifully in the protection of taller plants on Afton Down, while the uni-capitate form grows with it on Afton Down, but is extremely frequent on all the downs surrounding Alum Bay, and particularly on the one which extends to the Needles.

A sixth species of Erythræa is noted by Nyman as British in his recently published "Conspectus Floræ Europææ," part III., p. 502, viz: *E. diffusa,* Woods. It is of diffuse ascending habit, has few flowers, and the divisions of the corolla are as long as the tube. The lowermost leaves are elliptic subrotund, and approximate. I do not know on what authority it is regarded as British.

There are two other species of Erythræa whose continental distribution might almost lead to the hope of their being detected in Britain, or at least in the Channel Islands, since they occur on the contiguous French coasts. These are two very distinct Mediterranean species, viz: *E. spicata,* Pers., where each branch ends in a long red-flowered spike; and *E. maritima*, Pers., with yellow flowers.

I have carefully examined mature seeds of all the British species, except *E. latifolia*, Sm. (my specimens of which are not in fruit), and I can detect no differences amongst them of a specific character. The ripe seeds are of a russet brown in all the species except *E. pulchella*, and in this species they are blackish brown.

"On a dwarf form of *Campanula glomerata*, L., from the Isle of Wight," by CHARLES BAILEY, F.L.S.

When collecting *Erythræa capitata*, Willd., var. *sphærocephala*, Towns., in the Isle of Wight, referred to in the preceding communication, I was greatly struck with a diminutive *Campanula* which grows on the Afton Down at Freshwater, and still more plentifully on the downs from the Needles towards Freshwater. Its stature about Alum Bay is no greater than that of the herbage, which is extremely short, averaging only an inch; in the more sheltered ground opposite Freshwater it grows from one to three inches high. It is very unlike the ordinary form of *C. glomerata*, L., of the limestone districts of the North of England, which is of robust habit, frequently two feet in height, with a long spike of clustered flowers, or a single terminal cluster. The dwarf form of this species has been known for nearly a hundred years, as Withering in his "Arrangement of British Plants," 5th Ed., Vol. II., p. 310, thus refers to specimens from the identical locality:—

"I have gathered it when growing on a high and very dry soil, as on the summit of Aston [? Afton] Down in the

Isle of Wight, only from one to two inches high (see Pl. II. f. 8) [The 2nd plate in the 5th Edition comprises details of the inflorescence of grasses only] when it can scarcely be said to have a stem; bears only one or two flowers, with four stamens and frequently but two summits. In the summer of 1795 Mr. Watt brought me a series of specimens from the Isle of Wight, from one to ten inches high, and soon afterwards Mr. Turner informed me that on barren limestone hills in Norfolk it grows equally diminutive; though the blossom, as he observes, is as large as in the largest specimens, which he has sometimes seen above two feet high." He also mentions amongst the localities from which he has specimens:—"Close to Stonehenge, on Salisbury plain, very diminutive. Mr. Caley."

I am distributing, through the "Botanical Exchange Club of the British Isles," under the name of var. β. *nana*, the few specimens of this dwarf form which I collected. It differs from the typical form only in its diminutive parts, dwarf habit, short slender stem, and heads of one to three flowers. The colour of the corolla is paler than that of the ordinary erect form.

"On the Isle of Wight station for *Lychnothamnus alopecuroides*, Braun," by CHARLES BAILEY, F.L.S.

I also exhibit another interesting Isle of Wight plant, which had been thought to have become extinct, as it has not been reported to have been found for several years past, in the only British station where it is known to occur. This plant is the *Lychnothamnus alopecuroides*, Braun, one of the Characeæ, and was collected at Newtown, 14th July, 1881.

On the north coast of the Isle of Wight, between Cowes and Yarmouth, is a narrow creek with numerous arms, on whose shores many years ago a considerable trade was done in salt, produced by evaporation in the numerous salterns on each side of the creek. The newer method of obtaining salt from the brine formed by the beds of rock salt in Cheshire and other districts, has led to the abandonment of the salt pans at Newtown, and very few are now left. Some have been absorbed by the formation of oyster-parks on both sides of the creek, as well as by brick-works, and similar destruction threatens the remainder. The particular locality in which the *Lychnothamnus* occurred lies a few hundred yards north of the Coast Guard station at Newtown, and contiguous to the shores of the creek. At this spot are the remains of three old salterns containing water as salt (to the taste) as that of the sea, and filled with *Ruppia spiralis*, Hartm. The saltern nearest the creek is the only one of the three which contained the *Lychnothamnus*, and from it I obtained, by wading, a number of very fine plants, many of whose stems would be from 18 to 24 inches in length. They were greatly infested with a confervoid growth, which rendered it difficult to secure good-sized plants.

I spent some time in a subsequent visit, exploring some of the ramifications of the creek, but failed to find a trace of the plant in any other station. One of the large oyster parks on the western side of the creek was carefully, but unsuccessfully, searched during this second visit, its nearly empty condition affording every facility. The most likely station for its being found on the western side of the creek is at a spot where there are two old salterns, both of which had been emptied of their vegetation a few days previously, apparently to adapt them for duck-ponds.

Frankenia lævis, L., *Inula crithmoides*, L., and *Artemisia maritima*, L., were amongst the conspicuous plants of the same neighbourhood.

Ordinary Meeting, February 7th, 1882.

R. Angus Smith, Ph.D., F.R.S., &c., in the Chair.

"The Colour Sense and Colour Names," by William E. A. Axon, M.R.S.L.

The recent important paper of Dr. Schunck on the terms used to denote colour opens out the entire question—and a very fascinating one it is—of the origin and development of the colour sense. In the course of his opening address at the British Association Sir John Lubbock referred to the subject of blue blindness, a topic which has at once a practical and an archæological interest. Mr. Gladstone, in the course of one of his Homeric studies, made the suggestion that the ancient Greeks were unable to distinguish blue. As far back as 1858 Mr. Gladstone asserted "That Homer's perceptions of the prismatic colours, or colours of the rainbow, which depend upon the decomposition of light by refraction, and *a fortiori* of their compounds, were as a general rule vague and indeterminate." He however returned to the subject in an article which appeared in the *Nineteenth Century* for October, 1877. After analysing the Homeric epithets and referring to the investigations of Magnus and Geiger, he unequivocally adopts the suggestion that the colour sense was comparatively imperfect in the Homeric age. Mr. Gladstone's general conclusion is, that archaic man had a positive perception only of degrees of light and darkness, and that in Homer's time he had advanced to the imperfect discrimination of red or yellow, but no further; green of grass and foliage, or the blue of the sky being never once referred to. Dr. William Pole, who is himself colour blind, taking the instances cited by Mr.

Gladstone from Homer, thinks that they point to the colour blindness of the person using them. He thus summarises his conclusions:—

"1. That Homer's applications of colour epithets are in many cases inconsistent with the normal ideas in regard to them. This is the first and most general symptom of colour blindness. 2. That this inconsistency is particularly noticeable in the use of the expressions for red and green. This is a further and more definite symptom, showing the peculiarly defective sensations in regard to these particular colours. 3. But that when the objects referred to are classified in two groups according to the two colour sensations they respectively offer to the colour blind eye, the use of the colour epithets becomes consistent, no epithet belonging to one group being used, except in one doubtful case, for an object belonging to the other. This is a still more definite symptom, pointing, as it seems to me, to the dichromic nature of the malady."—*Nature,* Oct. 31, 1878, pp. 703-4. These results if accepted might be interpreted in two ways. It might be, and has been contended, that the Greeks generally were colour blind. If this be rejected, there remains the further possibility that the Homeric colour terminology was not a matter of racial but of individual peculiarity. In fact, that although the Greeks were not colour blind Homer might be.

Another disciple of the same school was the late Prof. Lazarus Geiger, who tells us that blue is not used as an epithet of the sky in the Rig-Veda, the Zend-Avesta, the Old Testament, the Homeric poems, nor in the Koran, and that Alkindi, writing in the 9th century, is the first to speak of the azure of the sky. Geiger also says that green is not named in the Rig-Veda, that Aristotle speaks of the rainbow as red, yellow, and green, that Xenophanes regarded it as purple, reddish, and yellow, and that Democritus regarded black, white, red and yellow as the fundamental colours, and that these, with the addition of green, are now so regarded in China. (See Geiger's Contributions to the History of the Development of the Human Race—London, 1880, pp. 48 *et seqq.*) Hence, as the Rig-Veda, the Zend-Avesta, the Old Testament, and the Homeric poems contain no reference to the sky as blue, it is argued that the peoples to whom these books belonged were incapable of discriminating the finer shades of colour. The weak part of such an argument is, that it may possibly confuse mere poverty of nomenclature with defective perception. This in effect is the reply of Seydewitz and others who are not able to accept the theory propounded by Geiger. In the Kaffir language, although there are more than twenty-six distinct names for the colouring and coat of cattle, one term is used for both blue and green, although the people who use it are perfectly well able to tell the one from the other. If we take the savages of the present day we see no reason to suppose that their appreciation of colour is inferior to that of civilized races. On the contrary, it is a constant source of regret to see the genuine æsthetic qualities of aboriginal art supplanted by European importations, often inferior both in form and colour. Dr. Hahn, whose recent work on the Hottentot race has excited much and deserved attention, says:—"that the Khoikhoi distinguished very strictly between white, black, green, red, blue, fawn-coloured, yellow, brown, grey and dotted. Then we have the following sub-divisions—whitish-yellow, whitish, black-patched, black-dotted, black-shining, red-shining, with white and red patches, chesnut-colour, reddish, green-shining, brown-dotted, 2 words, brownish-blue (the colour of Bucephalus Capensis), brown-shining, like the Vipera Cornuta. The colour of the rainbow is always green; only in two cases I heard that it was considered to be red. The name of the rainbow is tsawirub and dabitsirule. In Bible translations of missionaries we read tavi—! hanab. This is very incorrect, and nothing else but a verbal translation of *rainbow.*" Mr. Grant Allen has made extensive inquiries on this point, and his researches lead him to the supposition "that the colour sense is as a whole absolutely identical throughout all branches of the human race."

The reason why colour plays so subordinate a part in the older literature of various nations is chiefly the direct and simple manner in which the story is related. The ideas are concrete. The need of picturesque details does not occur to the writer or the singer. He is speaking often of familiar things, and feels no necessity to describe them. If he does enter upon description, the shining and glittering of spears and bucklers are more likely to arrest his attention than their precise colour. Mr. A. R. Wallace says that in the long epochs during which the colour sense was being developed the visual organs would be mainly subjected to two groups of rays:—the green from the vegetation, and the blue from the sky. This makes it all the more remarkable that blue should be so largely absent from early colour vocabularies. But much confusion has resulted from the poverty of the colour-vocabulary. In quite recent literature we find the same objects described by the terms "blue" and "green."

Green, as a beautiful colour of eyes, has been celebrated by many poets. "Green is indeed the colour of lovers," says Shakspere. Drummond, Cervantes, Longfellow, and Dante have all praised the green-eyed beauties. (There are many communications in *Notes and Queries*, 6th S., vol. I., and in the *Antiquary*, vol. III.) Moncrief says that the eyes of cats were for a long time the objects of female ambition; they could receive no praise more flattering than to discover that they had bluish grey eyes; that is, changing like those of cats, or greenish as they commonly have. La Fontaine has given Minerva such eyes,

> Tout le reste entouroit la déesse, aux yeux vers.

Marot gives green eyes to Venus,

> Le premier jour que Venus, aux yeux vers.

The lord de Coucy, so celebrated for his loves, acknowledges in his verses that such eyes were the secret charms that Madame de Fayel practised on him. These bluish grey eyes are those which commonly are of a pale blue, or sometimes of a water-colour which varies or undulates, with different shades, in the course of the day. The green eyes never change their shades. Diodorus Siculus tells us that Pallas was named by the Egyptians *Glaucopis,* that is, having eyes of a greenish white. And Pope's "blue-eyed maid" has been censured for being inexact; it should be "eyes of a bright citron." (*Histoire des Chats,* p. 127.) It is a custom in the East to *tinge* the eyes of women, particularly those of a fair complexion, with an impalpable powder prepared chiefly from crude antimony. It is of a purple colour, and a Persian compares it to the violet. The Arabian poets compare the eyelids of a fine woman bathed in tears to violets dropping with dew.

Shakspere has

Violets dim,
But sweeter than the lids of Juno's eyes.

Winkleman observes that "his researches concerning the mysterious art, said to be practised among the Greeks, of changing blue eyes into black ones, have not succeeded to his wish. I find it mentioned but once by Dioscorides. Could I have cleared up this art, it would have been a problem worthy to fix the attention of the Newtons and the Algarottis, and have interested the fair sex by a discovery so advantageous to their charms, especially in Germany, where large fine blue eyes are more frequently met with than black ones." The same author also notices the green eyes we have alluded to, and gives us the charming line in which the Sieur de Coucy describes the eyes of Madame de Fayel:

"Et si bel œil vert, et riant, et clair."

(The above and other references will be found in I. D'Israeli's

Romances, 1801, p. 123, and in the notes to Beckford's Vathek.)

The value of green is an ancient belief. "Wise architects," says Isidorus of Seville, "do not gild the ceilings of libraries, because the glitter might injure the eyes, and they pave them with green marble, for that is a colour salutary to the sight." Calderon, in one of his fine passages, says:—

> "La verde es color primera
> Del mundo, y en quien consiste
> Su hermosura."

Mahomet had the true poetic feeling in this matter, for a portion of his pleasures of Paradise was that the true believers should delight themselves lying on green cushions and beautiful carpets.

The late Mr. C. Babbage, F.R.S., whose philosophic spirit illuminated every question he discussed, made numerous experiments to discover the shade of colour most suited for reading as causing the least strain to the eye. He was then preparing his logarithmic tables, and a "Specimen" exists in 21 volumes, printed with different coloured inks and on variously coloured papers. "The object of this work," he says, "of which one single copy only was printed, is to ascertain by experiment the tints of the paper and colours of the inks least fatiguing to the eye. One hundred and fifty one variously coloured papers were chosen, and some two pages of my stereotype Table of Logarithms were printed upon them in inks of the following colours:—Light blue, dark blue, light green, dark green, olive, yellow; light red, dark red, purple, and black. Each of these twenty volumes contains paper of the same colour, numbered in the same order, and there are two volumes printed with each kind of ink. The twenty-first volume contains metallic printing of the same specimen in gold, silver, and copper, upon vellum and on variously coloured papers. For the same purpose about thirty-five copies of the complete Table of Logarithms were printed on thick drawing paper of various tints." Where is this wonderful and unique book now? Yellow was the colour of paper that had the preference, and the Table of Logarithms was printed for the public in black ink and on a deep shade of yellow paper. There is a review of the "Specimens" in Brewster's "Edinburgh Journal of Science," vol. vi. (1832), p. 144. The writer, probably Brewster, is in favour of the blackest ink upon the whitest paper. "The ground of this conclusion is that by looking through slightly coloured media we may give to the white paper any tint we desire without depositing a poison at the root of the ink." I fancy that those who can do without will be unwilling to read with coloured spectacles.

Returing from this digression it may be remarked that the speculations of Geiger are by no means universally accepted, and less so now than when they were first broached. Dr. Krause, an earnest follower of Darwin, opposes them; and Sir John Lubbock doubts. The matter has also been investigated by Dr. Paul von Seydewitz, of New Orleans, who also rejects the theory that the ancients were colour blind. Mr. Grant Allen, whilst holding that the colour-sense has been developed from the partiality of man's frugivorous ancestors for bright coloured fruit, is also a decided opponent of the idea that this has been done within the historic period.

In our own days the colour vocabulary is not used with exactness. Why, then, should we suppose that the Greeks were colour-blind because Homer appears to use the same name for red, purple, and grey? An exact scientific precision is not to be expected in the popular use of such terms. The very basis, however, of Geiger's theory is the exact conformity of colour sense and colour terminology, and when we see that this is notably absent in the present day amongst races of a lower degree of culture, we may conclude, until further evidence is forthcoming, that the Greeks of old were quite as well able as their modern descendants to appreciate the beauty of the blue sky although they had no word by which to express their admiration.

"Notes on Lead Pipes and Lead Contamination," by William Thomson, F.R.S.E.

The question of the contamination of water by lead pipes having been recently revived by Dr. Sedgewick Sanderson's translation of M. Belgrand's brochure, made in accordance with the instructions of the Commissioners of Sewers of the City of London, I propose to bring before the Society a few notes on the same subject which may be of interest.

About three years ago I examined a sample of water to ascertain whether it contained any objectionable ingredients, and found it to be contaminated with lead to the extent of 0·197 grains per gallon. The composition of this water was as follows:—

	Grains per Gallon.
Total solid matter	7·971
Organic matter, combined water, &c.	1·817
Saline matter	6·154

The saline matter was composed of:—

Chlorides of Sodium and Magnesium	1·543
Sulphates of Soda and Magnesia	1·146
Sulphate of Lime	2·328
Carbonates of Lime and Magnesia and Oxide of Iron	1·137
	6·154
Free Ammonia	·0028
Albuminoid Ammonia	·0035
Oxygen contained in Potassium Permanganate required to oxidise organic matters, &c., acting in the cold during three hours	·028
Nitrates and Nitrities	absent
Total Hardness	3° ·8

I advised that this water should not be used for drinking purposes on account of the lead which it contained, and I afterwards learned that one of the members of the family, being ill and under medical treatment, suspected that there might be something wrong with the water in question, because she was better in health when away from her home, and it was only after lead had been detected in the water that lead poisoning was even suspected by the medical attendant, and it then became evident that the patient was suffering severely from lead poisoning, all the symptoms being strongly marked. The gums were tinged of a bluish shade and the fingers of both hands had become stiff and partially paralysed.

The interesting points connected with this case are, that whilst a number of persons were using this water only one suffered severely from lead poisoning, although others of the family were in indifferent health previous to, and enjoyed good health after, the removal of the lead pipe which conveyed the water from the well to the house. As this lead pipe, which was in all probability the cause of all the unhealthiness of the family, had been in use for 21 years, it would have been interesting to have known the condition of health of the previous occupants of the same house, and if not satisfactory, to have learned whether or no any medical man diagnosed any of the cases as those of lead poisoning, as there seems little doubt that those who lived in this house must have suffered, more or less, from this cause. It seems, unfortunately, probable that many persons may be suffering from slow lead poisoning without the real nature of the malady being recognised by medical men, as it was in the case of the lady above mentioned, who by philosophical reasoning and experiment solved the problem which puzzled the doctor.

The house referred to was supplied from a well about 500 yards distant, the water passing by gravitation through a one-inch lead pipe, and although this pipe had been in use for 21 years, and the water which passed through it contained certain proportions of sulphate and carbonate of lime, yet the pipe had not become coated as M. Belgrand says is the case with the lead pipe in Paris, and as is generally supposed to be the case, but was, according to the description of the owner of the house, as free from inside coating when taken out as it was when put in.

I was asked to suggest a substitute for the lead pipe, and advised the use of tin-lined lead pipe where the coating was about 1-16th to 1-20th of an inch thick, because some samples which I had obtained and examined several years before did not in the slightest degree contaminate water when kept in the pipe for many days. My suggestions were carried out, and a sample of the water which had passed through this tin-lined pipe sent to me for examination. I found it to be contaminated with lead to a considerable extent, and on examining some of the tin lining I found it to contain a large proportion of lead. I sent to another manufacturer of this tin-lined pipe for a sample. This he sent me, and again I found that the tin lining contained a large proportion of lead, and quickly contaminated water left in contact with it. This I communicated to the manufacturer, who informed me that he could not understand how the tin lining had become contaminated, unless it was by its being poured down the side of a strip of lead into the hole left in the solidified lead in the cylinder previous to forcing it through the dies by hydraulic pressure. As I understand this pipe is produced by pouring melted lead into a cylinder, through the top of which an iron shape is introduced to make a cavity in the lead of sufficient size to hold the necessary quantity of tin; the lead is then allowed to set; when this occurs the iron shape is withdrawn and molten tin poured in to fill the space which the iron shape previously occupied; a "die" composed of an iron tube with a core dips into the tin, which remains liquid in the cavity, whilst this outer tube forms the core of another tube through which lead is forced, the innermost core being prolonged, so that the tin comes in contact with and solidifies on the interior of the lead pipe. It seemed to me remarkable that a manufacturer who was cognisant of the fact that tin dissolved lead should have allowed such a device as the pouring of the tin down a strip of lead to be employed for filling the mould.

These tin-lined lead pipes, I understand, are used to a large extent, and principally in making communication between the beer in the cask and the pump on the counters of beer retailers. Such pipes would give the idea of safety, but it is clear that many samples of it may be of such a nature as to contaminate beer with lead to a large extent, as the beer contains a certain amount of free acid which would in all probability be capable of dissolving the lead; and one would expect that the person who consumes the first glass of beer from the pump in the morning would get that which had remained over night in the pipe, and would imbibe, therefore, a considerable quantity, depending on the quality of tin lining, of the poisonous metal.

To test whether this was really the case, a few days ago I got two samples of beer, drawn in the morning, from two pumps at the same place, and examined them, and found a considerable proportion of lead to be present in each. To find whether it was possible to obtain tin-lined lead pipe, in which the tin was free from lead, for making communication between the house and well above mentioned, I obtained a number of samples of this variety of pipe from the same and from different manufacturers, and tested the purity of the tin lining inside each, but failed to find one which was not contaminated with lead, and which did not contaminate water when left in contact with it for two or three days to a greater or lesser extent; one or two samples, however, contained very little lead, and only caused a minute trace of contamination in the water, but the majority contained a large percentage of lead, and polluted the water to a great extent. Ultimately, the gentleman who occupied the house referred to had the tin-lined lead pipe which replaced the lead one dug up, and communication with the well established by 500 yards of block-tin pipe; and since this change was made, he informed me lately that his family have enjoyed good health.

There is another kind of lead pipe manufactured called "tinned lead pipe," the inside of which is covered with a very thin coating of a white metal to afford protection against the action of water on lead—as a matter of fact, this coating is not tin at all. It is produced by filling the first few inches of the ordinary lead pipe which is forced through the dies, whilst still very hot, with molten tin, which remains molten and washes the inner surface of the lead tube as it is produced. Presumably, when a long length of pipe has been forced through the dies, there would be little or no tin remaining, but I was informed by a manufacturer of this pipe that that is not the case; on the contrary, there is a much larger volume of tin, to use his own language, at the end of the operation than there was at the beginning; the molten tin dissolves the lead, thus increasing in volume, and so the coating is a mixture of lead and tin, the proportion of lead in the coating being greater in those portions of the pipe which are last forced through the die.

Some years ago, not knowing of the existence of this kind of tinned lead pipe, I requested a plumber to make for me a worm refrigerator with tin-lined lead pipe for the preparation of distilled water. He did so, and to my astonishment, on testing the distilled water which had been condensed in it, I found it to contain a large proportion of lead. On examination of the pipe afterwards I found it to be the variety which had been washed with tin. This coating cannot therefore be regarded as a thoroughly efficient protection against the action of water on lead, but the test was a severe one, and there can be no doubt that tin-coated lead pipe is much better adapted for use in making communication with the water mains in large towns than the ordinary lead pipe, whilst the cost of producing this coating, I understand, amounts to only a few shillings per ton of pipe. To test their respective values I placed water containing a small proportion of nitrate of ammonia in two pipes of the same sizes, the one tinned inside, the other the ordinary lead pipe. After standing about three hours I tested the water from each, the one from the tinned lead pipe contained only a trace of lead, whilst that from the ordinary lead pipe contained a large proportion of lead in solution. Similar results were obtained by leaving Manchester water in the same pipes for 18 hours.

In certain boroughs, I understand, such as Salford, Oldham and Southport, this tinned lead pipe is the only kind allowed to be used for making communication with the main, whilst in Manchester and other places ordinary lead pipe is generally employed. I have lately observed that the lead pipes which have been in use in Manchester for many years contaminate water left in them over the night to a considerable extent, but after the water has been used for a short time during the day it is free from any appreciable trace of lead.

I have also tested the water after remaining 18 hours in the lead pipes in communication with the main in Salford where the tinned pipes are employed, and although the water was slightly contaminated with lead, it contained much less than that found in the water which stood for the same length of time in the ordinary lead pipes of Manchester.

It is a fact, which I have observed from my experience during the last few years, that aërated waters are contaminated with lead much more often, and in many cases to a much greater extent than one would expect, considering the attention and care which is bestowed by good firms on the manufacture of these articles. Lately I tested several samples of what was termed "pure" carbonate of potash, and "pure" carbonate of soda, and citric acid, which were specially purified for use in the preparation of aërated waters, and I found all to be contaminated with lead to a greater or less extent. The manufacturer of these samples was apprised of this fact, and in reply he admitted that they contained traces of lead, but said it was impossible to obtain these substances free from metallic contamination at anything like reasonable cost, and he was quite satisfied that the quantity was not objectionably large. To overcome this difficulty I had to advise the use of the ordinary carbonate of soda, made by Solvay's ammonia process, as being almost as pure, and certainly much less likely to be injurious than the purified salt. I also advised that those salts which it is impossible to obtain free from lead should be dissolved in water, and filtered through or boiled with animal charcoal, which has the property of removing the lead from solution. It might here be noted that the use of charcoal filters diminishes very much the risk of lead poisoning, as the charcoal removes any trace of lead which the water might contain.

It was first discovered and afterwards published by the late Dr. Crace-Calvert and Mr. Richard Johnson in a joint paper, that pure lead is more easily acted on by sulphuric acid than lead containing a very small percentage of impurities such as antimony and copper, and these results have been repeatedly verified since. With a view to find the effect of pure water on comparatively pure lead and on lead to which I added $\frac{3}{4}$ of a per cent of antimony, I melted some of the original lead and poured some out, which I rolled into a sheet. Antimony was added to the remainder, and the mixture poured out and rolled into a sheet as before; both sheets were cut to the same size and placed in equal bulks of distilled water and left overnight. In each case a fine white flocculent crystalline matter, an oxide or salt of lead, was observed in suspension, but this existed in considerably greater proportions in the water containing the lead which had not been treated with antimony. Thus the small quantity of antimony appears to afford some protection against oxidation of the lead by air and water. When the suspended matter was filtered off, only a trace of the lead was found to be in solution in each case.

It is sometimes advisable to obtain the lead contained in water in a contracted solution, and preferably in an acetic acid solution if possible. I have observed frequently that weak acetic acid dissolves no lead from the residue left on evaporating waters which gave originally a very distinct coloration with sulphuretted hydrogen, but on treating the residue with strong nitric acid, evaporating off the acid completely and again treating the residue with weak acetic acid, the lead dissolves with apparent facility, and on evaporating this acetic solution of the metal to a drop or two, it may be obtained in a sufficiently concentrated solution for the application of the other tests. It appears as if certain organic matters contained in the water combine with and render the lead insoluble in acetic acid; these organic substances being afterwards decomposed by the nitric acid, leave the lead in a condition in which it is soluble in acetic.

A curious case of lead poisoning lately came under my notice and engaged the attention of a Lancashire coroner. A woman, upon whose body the inquest was held, had been employed in weaving cloth from yarn, which had been dyed of a yellow colour. The colour was the ordinary chromate of lead, and it was alleged that the dye had caused her death by poisoning.

I examined some of this yarn, which I found to be of an orange yellow colour due to the chromate of lead which had been fixed in the fibre, but it was so loosely fixed that by gently shaking a hank the chromate came out, forming a cloud of yellow dust, and it was given in evidence at the coroner's court that all or nearly all the workpeople who had been engaged in weaving this cloth suffered more or less from lead poisoning.

I afterwards examined some yarns containing the same pigment colour fixed in the thread so firmly that it could not be removed by shaking.

Ordinary Meeting, February 21st, 1882.

Dr. R. Angus Smith, F.R.S., &c., in the Chair.

Dr. Schuster, F.R.S., exhibited and explained "Grant's Arithmometer."

Ordinary Meeting, March 7th, 1882.

Dr. R. Angus Smith, F.R.S., &c., in the Chair.

"A Comparison between the Height of the rivers Elbe and Seine and the state of the Sun's Surface as regards Spots," by Professor Balfour Stewart, LL.D., F.R.S.

1. Certain results connected with the Nile and the Thames which were recently brought before me (see *Nature*, Jan. 19, 1882) have led me to think that if we suppose there is a connexion between the state of the sun's surface and the heights of rivers, the nature of this connexion will probably be best expressed by supposing that there are traces of a double as well as of a single fluctuation in river heights during a single sun-spot period. A similar observation has,

I think, already been made with regard to the connexion between sun-spots and rainfall.

2. To test this I have taken the heights of the rivers Elbe and Seine as recorded by Professor Fritz, and I am indebted to the kindness of Professor Archibald for bringing the memoir of Professor Fritz before me. There is a long series of heights for both these rivers, these heights being expressed in metres above a certain mark.

These heights have been arranged according to the sun-spot cycle after the following method. The dates of the various maxima of sun-spots, as given by Professor Wolf in his most recent memoir, are taken as the starting points, or 0 and each interval between successive maxima is divided into 12 equal parts called 1, 2, 3, 4, ... 11, 0, no further regard being had to the inequalities in the lengths of the various periods. The river heights corresponding to the dates of these various subdivisions have been obtained from Professor Fritz's results by a simple interpolation.

3. This method will be easily understood by reference to the following tables.

Table I.*

HEIGHT OF THE ELBE.

Period commencing with maximum	0·5	1·5	2·5	3·5	4·5	5·5	6·5	7·5	8·5	9·5	10·5	11·5
1727·5	2·19	2·55	2·81	2·79	2·67	2·74	2·31	2·87	2·84	2·78	3·14	2·97
1738·7	3·06	3·04	3·00	2·89	2·78	2·74	3·10	3·01	2·45	2·82	3·06	2·88
1750·3	2·64	2·62	2·39	2·57	2·65	2·90	2·89	2·74	2·44	2·28	2·57	2·66
1761·5	2·52	2·50	2·53	2·84	2·95	2·62	2·45	2·45	2·60	2·60	2·76	3·19
1769·7	3·60	3·77	3·67	3·02	2·64	2·60	2·83	2·83	2·67	2·57	2·80	2·83
1778·4	2·65	2·42	2·61	3·19	2·82	2·68	2·82	2·17	2·54	2·75	2·62	2·33
1788·1	2·49	2·47	1·97	2·10	1·72	2·14	2·24	2·31	2·55	1·84	2·22	2·30
1804·2	2·92	2·95	2·60	2·28	2·04	1·88	1·63	1·83	2·15	1·82	1·78	2·06
1816·4	2·21	1·86	1·98	1·82	2·26	1·85	1·76	2·13	1·89	2·00	2·34	2·44
1829·9	2·41	2·46	2·42	1·85	1·69	1·94	1·89	1·74	1·44	1·35	1·47	1·87
1837·2	2·24	2·20	2·33	1·91	1·98	1·58	1·91	2·34	2·21	1·99	2·04	2·04
1848·1	1·67	1·88	2·35	2·34	2·02	2·10	2·22	2·32	1·84	1·45	1·57	1·62

* It was intended to make the recorded numbers correspond to the divisions 0, 1, 2, &c., but by an accident it was the above intervals which were recorded. This does not affect the result obtained.

Table II.*

HEIGHT OF THE SEINE.

Period commencing with maximum	0·5	1·5	2·5	3·5	4·5	5·5	6·5	7·5	8·5	9·5	10·5	11·5
1738·7	1·20	1·53	1·37	0·93	0·90	1·15	1·20	1·14	1·25	1·19	1·06	1·14
1750·3	1·21	1·82	1·08	1·13	1·09	1·02	1·72	1·32	1·32	1·11	1·37	1·27
1761·5	0·93	0·97	1·01	1·35	1·47	1·08	0·79	0·73	0·92	1·03	1·23	1·55
1769·7	1·84	1·80	1·55	1·57	1·30	1·31	1·74	1·24	1·01	1·02	1·03	1·16
1778·4	1·19	1·15	1·41	1·07	1·24	1·34	1·23	1·22	0·84	1·08	1·47	1·57
1788·1	1·10	1·34	1·19	1·64	0·92	1·19	1·21	1·00	1·46	0·82	1·67	0·83
1804·2	1·32	1·41	1·54	1·38	1·22	1·52	1·15	1·32	1·30	0·96	0·98	1·44
1816·4	2·05	1·43	1·08	1·09	1·18	0·75	1·08	1·52	0·99	0·92	1·13	1·34
1829·9	1·10	1·25	1·36	0·93	0·88	1·19	1·06	0·88	0·91	1·23	1·85	1·83
1837·2	1·60	1·15	1·55	1·17	1·56	1·06	1·05	1·23	1·40	1·54	1·43	1·20

4. In the following table the results of tables I. and II. for both rivers are divided into two equal parts, the various sums for these being given in the first four columns. In the next four these sums have been somewhat equalised by taking their sums in threes, while in the last four columns departures from the mean as derived from the second four columns are given.

Table III.

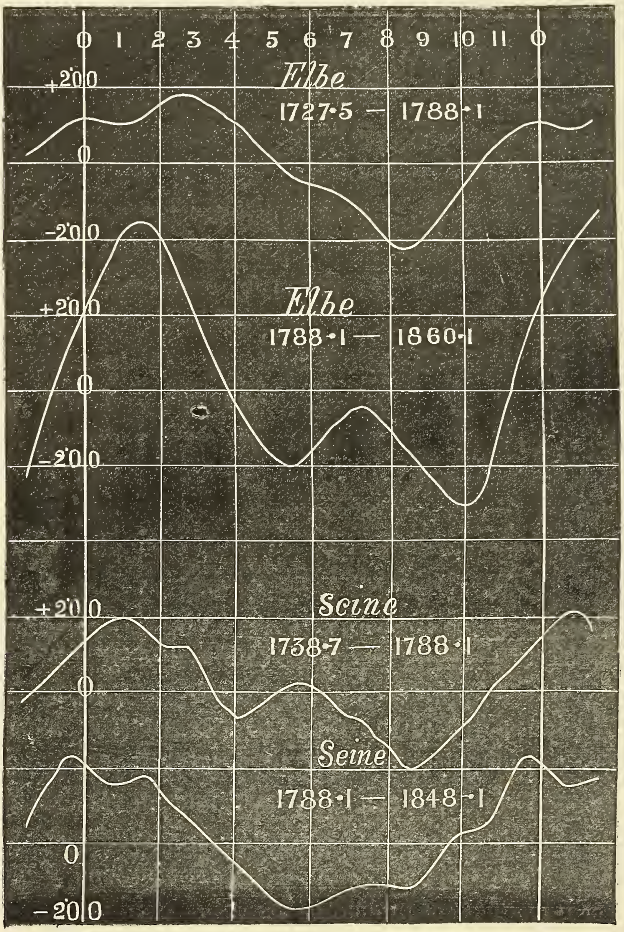
HEIGHTS OF RIVERS ELBE AND SEINE.

ELBE.		SEINE.		ELBE.		SEINE.		DEPARTURES. ELBE.		DEPARTURES. SEINE.	
1st 6.	2nd 6.	1st 5.	2nd 5.	1st 6 equalized.	2nd 6 equalized.	1st 5 equalized.	2nd 5 equalized.	1st 6	2nd 6.	1st 5.	2nd 5.
16·66	13·94	6·37	7·17	50·42	40·09	20·33	20·39	+0·85	+3·21	+1·84	+1·67
16·90	13·82	7·27	6·58	50·57	41·41	20·06	20·47	+1·00	+4·53	+1·57	+1·75
17·01	13·65	6·42	6·72	51·21	39·77	19·74	19·51	+1·64	+2·89	+1·25	+0·79
17·30	12·30	6·05	6·21	50·82	37·66	18·47	18·69	+1·25	+0·78	−0·02	−0·03
16·51	11·71	6·00	5·76	50·09	35·50	17·95	17·68	+0·52	−1·38	−0·54	−1·04
16·28	11·49	5·90	5·71	49·19	34·85	18·58	17·02	−0·38	−2·03	+0·09	−1·70
16·40	11·65	6·68	5·55	48·75	35·81	18·23	17·21	−0·82	−1·07	−0·26	−1·51
16·07	12·67	5·65	5·95	48·01	36·40	17·67	17·56	−1·56	−0·48	−0·82	−1·16
15·54	12·08	5·34	6·06	47·41	35·20	16·42	17·48	−2·16	−1·68	−2·07	−1·24
15·80	10·45	5·43	5·47	48·29	33·95	16·93	18·59	−1·28	−2·93	−1·56	−0·13
16·95	11·42	6·16	7·06	49·61	34·20	18·28	19·17	+0·04	−2·68	−0·21	+0·45
16·86	12·33	6·69	6·64	50·47	37·69	19·22	20·87	+0·90	+0·81	+0·73	+2·15

* It was intended to make the recorded numbers correspond to the divisions 0, 1, 2, &c., but by an accident it was the above intervals which were recorded. This does not affect the result obtained.

5. The departures shown in the last columns of table III. are exhibited graphically in the diagram which accompanies this paper. It will be noticed that in each of the four curves there is a river maximum shortly after the maximum of sun-spots, and that there are also traces of a subsidiary maximum a good deal farther on, so that the curve gives indications of a double as well as of a single period.

In conclusion I desire to express my thanks to Mr. Henry Stroud for assistance rendered in this investigation.



Mr. Wilde exhibited two electro-motor machines for illustrating the transmission of mechanical power by means of electricity. He remarked that soon after the discovery of electro-magnetism numerous attempts were made to turn the principle to account for the production of motive power. It was soon found, however, from experiments made by Joule and others, that the expense of motive power derived from the voltaic battery was so great as to render its use as a substitute for the steam engine quite impracticable, and the subsequent production by himself and others of powerful electric currents by the reverse action of steam power and electro-magnetism, had served to confirm the convictions previously formed as to the futility of all attempts to obtain motive power economically from voltaic electricity in substitution of the power derived from steam. Fallacies respecting the economic production of electro-motive power were nevertheless more prevalent than might commonly be supposed, as the records of the Patent Office continually showed; and a notable instance was brought before this Society a few years since by an eminent telegraph inventor who endeavoured to prove that the coal consumed in furnishing the power required in Manchester factories would be more economically employed in smelting zinc to be used in voltaic batteries for the production of motive power than in the generation of steam for the same purpose.

While the progress of electrical science had proved most clearly that electricity could not compete successfully with steam in point of economy, recent experiments had shown that it might, in some cases, be utilised as a transmitter of motive power to points at a considerable distance from the prime mover.

There were no doubt many circumstances in which the method might be used with advantage, but as the transmission of mechanical power by electricity was attended by a considerable loss of the original power employed, its application would only be of value where the circumstances of locality and distance prevented connexion with the prime mover being made by ordinary mechanical means.

Ordinary Meeting, March 21st, 1882.

Dr. R. Angus Smith, F.R.S., &c., in the Chair.

"Note on Envelopes and Singular Solutions, continued from vol. XVII. p. 15," by Sir James Cockle, F.R.S., F.R.A.S., Corresponding Member of the Society.

6. Lagrange (*Leçons*, 1806, p. 178) observes that singular values had presented themselves almost at the birth of the calculus; but since the theory of arbitrary constants was scarcely known at the time, these values were not regarded as exceptions to general rules. He adds that Euler was the first who looked at them in this point of view, and who gave rules for distinguishing them from ordinary integrals.

7. I shall follow Lagrange, and ascribe to Euler the first real recognition of singularity. So far as I know there is no proof that by a singular solution Taylor meant more than a solution obtained by differentiation.

8. In a letter to me, dated January 15th, 1867, Mr. Robert Rawson announced two theorems, which I give in a footnote.* I mention this, not as claiming priority for Mr. Rawson, but as stating his views.

* "(A)" "The condition of equal roots with respect to (C) in the complete primitive φ $(x, y, C)=0$ is a singular solution."

"(B)" "The condition of equal roots of φ $(x, y, p)=0$ with respect to p, is a singular solution if it satisfies the differential equation."

Mr. Rawson adds that the usual infinity tests are consequences of the condition, and that if the condition does not lead to a solution of a differential equation it is because the equation has not been derived from a

9. Lagrange, in fact (*ib.* pp. 182—183), observes that since the derived equation $F'(a)=0$ contains the condition which renders two of the roots of $F(x, y, a)=0$ equal, consequently the singular value of y gives to the last equation a double root.

10. Lagrange also remarks (*ib.* p. 219), that the singular primitive of $f(x, y, y')=0$ is obtained by the aid of the two equations $f'(y')=0, f'(x, y)=0$ and the elimination of y' by means of the proposed equation. He adds that if the two results give the same relation between x and y that relation will be the singular primitive; if not, it will be a sign that the proposed equation has no such primitive.

11. But $f'(y')=0$ is the condition of the equality of two of the roots of the given differential equation, treated as an equation in y'.

12. Mr. (now Prof.) Cayley long ago stated that the singular solution is the result of the elimination of the arbitrary constant between the primitive and its derived equation with respect to the constant (Q. J. of Math., 1860, vol. III., p. 36; see also the Messenger of Math., N. S.,

complete primitive involving an arbitrary quantity of two or more dimensions or that each of the roots requires a multiplier.

I take this opportunity of observing that in a letter to me, dated August 20th, 1862, Mr. Rawson remarks that an equation deduced from a cubic by one differentiation can be made linear by a proper assumption. Such a linear equation I call a first linear resolvent.

I also remark that I have verified one of the results of Mr. Rawson's recent paper (*ante*, p. 59). We may infer from what I proved years ago (see Phil. Mag. for May, 1861), that every cubic in y has a second linear resolvent of the form $y''+\nu y'+\mu y=M$.

Hence, slightly generalizing the process given in my Second Chapter on Coresolvents (Q. J. of Math., vol. VI., p. 226), we get

$$\Sigma y''+\nu\Sigma y'+\mu\Sigma y=3M$$

or, putting $\Sigma y=a$,

$$a''+\nu a'+\mu a=3M$$

and M vanishes with a. Next I find

$$\nu=-\frac{d}{dx}\log(vu'-uv')$$

and, summing again, I, after easy reductions, verify Mr. Rawson's logarithmic coefficient. I have not calculated μ, but the process is applicable to μ.

1874, vol. XXXVI., p. 179). The Rev. Robert Carmichael has given a paper on Singular Solutions (Phil. Mag., 1858, vol. XV., p. 522), on which I need not here comment.

13. Professor Cayley has also (see Messenger of Math. for May, 1872, p. 6; for June, 1876, p. 23), given a new theory of the whole subject which may be stated, not perhaps with perfect fulness, as follows: The locus represented by the discriminant, with respect to the arbitrary constant, of the primitive is made up of the nodal locus twice, the cuspidal locus three times, and the envelope locus once; and the locus represented by the discriminant with respect to p of the differential equation is made up of the envelope locus, cuspidal locus and tac-locus, each of them once.

14. This theory of Professor Cayley's seems to account thoroughly for the extraneous factors which occur in the processes for obtaining singular solutions.

14. Take a set of circles each of which touches both axes of rectangular coordinates and apply the Cayley theory. The primitive is $(y-c)^2+(x-c)^2=c^2$, the c-discriminant is $-2xy$ and $xy=0$ is made up of the envelope-locus once, viz., $x=0$ appears once and $y=0$ appears once. The p-discriminant is $-2xy(x-y)^2$, which is made up of the envelope-locus once and of the tac-locus. At first sight the tac-locus seems to occur twice. But $x=y$ is the bisector of the right angle at which the axes meet, and there is external contact of non-consecutive primitives at each end of that diameter of any one of them which when produced passes through the origin; and I imagine that when the parameter gradually varies each end of such a diameter must be held to trace a distinct tac-locus, so that $(x-y)^2=0$ gives each tac-locus only once. If this be so then, generally, when two non-consecutive primitives touch a primitive not consecutive to either of them each point of contact must be held to give rise to a distinct tac-locus, even when the path taken by one such point is the same as that taken by the other.

2, Sandringham Gardens, Ealing,
Near London, W., March 16th, 1882.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

February 13th, 1882.

ALFRED BROTHERS, F.R.A.S., President of the Section, in the Chair.

"List of the Phanerogams of Key West, South Florida, mostly observed there in March, 1872," by J. COSMO MELVILL, M.A., F.L.S.

The flora of this small island is limited, and naturally, to a great extent, maritime. In the year 1875 I recorded in the Journal of Botany a catalogue of the Algæ—it is by no means so rich, proportionately, in flowering plants or ferns.

Key West, which is entirely of coral formation, constitutes one of many small reefs or 'keys' which extend from Biscayne Bay westward to the Tortugas. Of these islets, this, which measures some seven miles in length, by one to one and a half in breadth, is the only one inhabited, and it is not likely that the others would present many botanical novelties, though but few of them have been explored. Boca Chica, the next island, is separated at low water by only a very narrow channel. It is densely wooded, and the character of the vegetation is entirely the same.

The south-western portion of Key West is cultivated, and towards the south and south-east, between the town and the sea, there are numerous green lanes and shady natural avenues, extending for a mile or two, which present a native flora of much beauty, though somewhat scanty in actual species.

The northern shores of the island are swampy, and there are extensive mangrove flats. It is in this portion that the original 'scrub' forest still remains, and the north-eastern shores especially present a deserted appearance.

Chapman, in his Flora of the Southern States, gives some Key West localities, mainly on the authority of the late Dr. Blodgett, and Grisebach (Flora of the British West Indian Islands) in his ample tables of distribution of each species, occasionally does the same. Mr. W. T. Féay, of Savannah, Georgia, lived for a year or more on the island, and collected several species I did not observe. These have been added to this list, on his authority, to make it more complete.

In the Shuttleworth Herbarium, now incorporated with that of the British Museum, there are several specimens of Key West plants, mostly collected by Rügel.

Owing to Key West being a town of increasing importance, as it is a military as well as a naval station, and also a calling point for all the steamers plying between New Orleans and Cuba, it is quite probable that the whole place may in a few years be materially changed, and by the clearing away of the old original 'bush' the flora may undergo complete alteration.

It will be observed that the flora is completely Carribean, and presents hardly any connection with that of the mainland of Florida, with the exception of that small portion south of the 'Everglades.'

* denotes that the plant is not originally indigenous.

PAPAVERACEÆ.

1. *Argemone Mexicana* (L.) native, according to Chapman, and exceedingly abundant in most places.

CRUCIFERÆ.

2. *Lepidium Virginicum* (L.). A more slender form than the ordinary plant. Common.
3. *Cakile Æqualis* (L'Her). Shifting sands of the south coast, Key west. Differs from C. Maritima (L.) in the shape of the upper fruit joint.

CAPPARIDACEÆ.

4. **Gynandropsis pentaphylla* (D.C.). Occasionally in waste places.
5. *Capparis Jamaicensis* (Jay). Rare (Mr. Féay).

6. *Capparis Cynophallophora* (L.). Occasional (Mr. Féay).

PORTULACACEÆ.

7. *Portulaca oleracea* (L.). Everywhere, especially on paths and clearings in the bush. Flower yellow.
8. *Portulaca pilosa* (L.) Rare. Flowers purple.

MALVACEÆ.

9. *Sida rhombifolia* (L.). Everywhere, in many forms.
10. *Sida stipulata* (Cav.) „ „

[I did not observe S. ciliaris (Car.) and S. Lindheimeri (Gray) noted in Chapman's Flora, p. 55, as occurring at Key West.]

11. *Abutilon crispum* (Gray). Not common.
12. *Hibiscus Floridanus* (Shuttl).
13. *Hibiscus Rosa Sinensis* (L.). Escape from cultivation.
14.**Gossypium Barbadense* (L.). Large shrubs occur towards the Lighthouse, S.W. corner of Key West.

[Ayenia pusilla (W.) nat. ord. Byttneriaceæ has occurred.]

TILIACEÆ.

15. *Corchorus Siliquosus* (L.).

OLACACEÆ.

16. *Ximenia Americana* (L.). (Mr. W. T. Féay).

AURANTIACEÆ.

17.**Citrus Aurantium* (L.). Very abundant in the S.W. quarter of the island, though no doubt originally imported.

MELIACEÆ.

18.**Melia Azederach* (L.). The Pride of India is planted in nearly all villages and towns in Florida.

OXALIDACEÆ.

19. *Oxalis stricta* (L.). Everywhere.

ZYGOPHYLLACEÆ.

20. *Tribulus cistoïdes* (L.). Superficially resembling Potentilla anserina (L.).

[Kallströmia maxima, Torrey and Gray, was not observed, though it has occurred at Key West].

21. *Guiacum sanctum* (L.). S. portion of the island, not common.

RUTACEÆ.

22. *Zanthoxylum Pterota* (H.B. & K.). Fagara lentiscifolia (W.). One of the most abundant shrubs of the island, but impossible to preserve for herbarium purposes, as the joints of the petiole disintegrate immediately when dry.

SIMARUBACEÆ.

23. *Simaruba glauca.* (D.C.) One of the most conspicuous trees of the island, with large and handsome pinnate leaves, and panicles of small green flowers.

BURSERACEÆ.

24. *Bursera gummifera.* (Jay.) A large tree (Mr. Féay).
25. *Amyris Floridanus.* (Nutt.)

ANACARDIACEÆ.

26. *Rhus Metopium.* (L.) A good sized tree; common.

VITACEÆ.

27. *Vitis* (*Cissus*) *acida.* L. Not uncommon in the S.W. portion of the island. It disintegrates in drying, as Z. Pterota.

RHAMNACEÆ.

28. *Scutia ferrea.* (Brong.) (Mr. W. T. Féay.) = (Condalia) (Cav.)
29. *Gouania Domingensis.* (L.) Common.

CELASTRACEÆ.

30. *Schœfferia frutescens.* (Jacq.) Abundant.
31. *Maytenus phyllanthoides.* (Benth.) Leaves very fleshy. Common in salt marshes.

LEGUMINOSÆ.

32. *Indigofera leptosepala.* (Nutt.) (Mr. W. Féay.)
33. *Galactia spiciformis.* (Torr and Gray.) Common.
34. *Piscidia erythrina.* (L.) The Jamaica Dogwood. Not common.
35. *Cassia occidentalis* (L.). Waste places.
36. *Cassia biflora* (L.).
37. **Parkinsonia aculeata* (L.). Not mentioned in Chapman's Flora, and possibly a recent introduction, but I obtained it from a remote quarter of the island, where was no cultivation. It is a remarkably elegant tree, with spikes of orange yellow flowers.

37A. **Tamarindus indicus* (L.). Quite naturalized and common.

38. **Poinciana pulcherrima* (L.). Near the town of Key West. Now referred by most authors to the genus Caesalpinia.
39. *Pithecolobium Unguis Cati* (Benth). Very abundant by the sea in the south portion of the island.
40. *Pithecolobium Guadalupense* (Desv.). Not so frequent as the last, of which it is probably a variety.

41.**Acacia* (*Albizzia*) *Julibrizzin* (W.). Not unfrequent, naturalized.

42.**Acacia* (*Vachellia*) *Farnesiana* (W.). This is almost the most abundant shrub in the western portion of the island. Not being mentioned in Chapman's Flora must surely be an error.

43. *Desmanthus diffiusus* (Willd). North shore of Key West. A prostrate form.

44. *Guillandina Bonducella* (L.). Very abundant on sandy ground near the South Fort. Not recorded in Chapman's Flora, though apparently wild.

MYRTACEÆ.

45. *Eugenia Monticola.* (D. C.) Abundant throughout the island.

46. „ *buxifolia.* (Willd.) „ „ „

47. „ *procera.* (Poir.) „ „ „

48. *Calyptranthes Chytraculia.* (Swartz.) Not uncommon.

RHIZOPHORACEÆ.

49. *Rhizophora Mangle.* (L.) Mangrove. With Avicennia oblongifolia on the north shore of Key West.

COMBRETACEÆ.

50. *Conocarpus erecta.* (Jacq). On sand by the S. shore. Leaves remarkably white and silky.

51. *Terminalia Catappa.* (L.) Very abundant.

52. *Laguncularia racemosa* (Great). North shore. (Mr. W. T. Féay.)

CACTACEÆ.

53. *Cereus monoclonos.* (D. C.) Very conspicuous from its tall, column-like stems, 10 to 12 feet high. It is used, with Agave Americana and Opuntia polyantha, for hedges, and the three form an impenetrable barrier.

54. *Opuntia vulgaris* (L.) var. *polyantha.* Abundant everywhere.

PASSIFLORACEÆ.

55. *Passiflora angustifolia.* (Sw.) Not common. (Mr. Féay.)

CUCURBITACEÆ.

56. *Sicyos angulatus.* (L.)

CRASSULACEÆ.

57.**Bryophyllum calycinum.* (L.) Very abundant. Not included in Chapman's Flora.

SURIANACEÆ.

58. *Suriana Maritima* (L.). Very abundant on the south shores of the island.

RUBIACEÆ.

59. *Spermacoce tenuior* (L.). Common in waste places.
60. *Ernodea littoralis* (S.W.) Not uncommon; flowers sweet-scented.
61. *Morinda Roioc* (L.).
62. *Chiococca racemosa* (Jacq).
63. *Hamelia patens* (Jacq). A very handsome shrub, with scarlet flowers. Western shores of the Island.
64. *Randia aculeata* (L.). (Mr. W. T. Féay.)
65. *Exostemma Caribbæum* (R. & S.). (Mr. W. T. Féay.)

[Erithalis fruticosa (L.) has been found also at Key West.]

[Guettarda elliptica (S.W.) Key West, Rügel in Herb. Shuttleworth, Mus. Brit.]

COMPOSITÆ.

66. *Cœlestina maritima* (Torr & Gray). [Ageratum L.] South shores of Key West. Abundant.
67. *Parthenium Hysterophorus* (L.). By roadsides very abundant.
68. *Iva imbricata* (Walt.). Sandy shores.
69. *Ambrosia Crithmifolia* (D. C.). Very abundant along the southern shores.
70. *Borrichia arborescens* (D. C.). Salt marshes, abundant.

70A. *Borrichia frutescens* (D.L.). Not so common as the last.

[Cosmos caudatus (Kunth.) occurs at Key West, but was not observed.]

71. *Bidens leucantha* (Willd.), a common tropical weed.
72. *Pluchea purpurascens* (D. C.), very common.
73. **Verbesina* (*Ximenesia*) *encelioides* (D. C.). Abundant. Not included in Chapman's Flora.
74. *Flaveria linearis* (Jay). Common.
75. *Sonchus oleraceus* (L.). Southern shores of Key West.

SAPOTACEÆ.

76. *Mimusops Sieberi* (A. D. C.). (=M. dissecta (R. Br.). Very abundant. A handsome tree. South shores of Key West.

THEOPHRASTACEÆ.

77. *Jacquinia armillaris* (Jacq). (Mr. W. T. Féay).

Myrsinaceæ.

78. *Ardisia Pickeringia* (Torr and Gray). A fine shrub, or small tree, flowering conspicuously in March.

Plumbaginaceæ.

79. *Plumbago scandens* (L.). Amongst Opuntia, in dry, stony places, very abundant. Flowers white.

Bignoniaceæ.

80. *Tecoma stans* (Jussieu). Rare, flowers very large, golden yellow.

Scrophulariaceæ.

81. *Herpestis peduncularis* (Beuth). Not uncommon, flowers small yellow. Turns quite black in drying, in common with most members of this family.
82. *Capraria biflora* (L.). Very common. Flowers varying from rose pink to white.

Acanthaceæ.

83. *Dipteracanthus linearis* (Torr and Gray.)
84. *Dicliptera assurgens* (Juss) = *D. sexangularis* (L). S.W. of Key West, among cacti; flowers scarlet.

Verbenaceæ.

85. *Priva echinata* (Juss).
86. *Stachytarpheta Jamaicensis.* (Vahl.) Exceedingly abundant all round the coast, the flowers bright blue in linear spikes.
87. *Lippia* (*Zapania*) *nodiflora* (Michx). Very common.
88. *Lantana involucrata* (L.) var. Floridana. The most frequent shrub on the island. Chapman (Flora S. States, p. 308) queries the colour of the corolla. It is white with a purplish tinge in the tube.
89. *Citharexylum villosum* (L.)
90. *Avicennia oblongifolia* (Nutt). Common with the mangrove in swamps.

Labiatæ.

91. *Ocimum Campeachianum.* (Mill.) Abundant, flowering in January and February.
92. *Salvia serotina* (L.) Abundant.
93. *Leonotis nepetæfolia.* (R. Br.) Rare in the S.W. portion of the island.

BORRAGINACEÆ.

94. *Cordia bullata* (L.). Rare. (Mr. W. T. Féay.)

95.**Cordia Sebestena* (L.) Probably not native. Near the town of Key West.

96. *Ehretia Buerreria* (L.). In the N. part of the island, but not common.

97. *Ehretia tomentosa* (G. Don.), var. *Havanensis* (W.). Very rare; one bush only observed, the central part of the island; not in Chapman's *Flora*, though Grisebach mentions its occurrence.

98. *Tournefortia Gnaphalodes* (R. Br.). By the sea shore, very abundant.

99. *Gnaphalodes volubilis* (L.). Climbing up trees in the N. portion of the island.

100. *Heliotropium Curassavicum* (L.). Salt marshes, common.

101. *Heliotropium myosotoïdes* (Chapman).

102. *Heliophytum parviflorum* (D.C.). Abundant.

CONVOLVULACEÆ.

103. *Pharbitis hispida* (Chois.). Very abundant as a climber in the N. portion of the island, flowers deep purple blue, very showy.

104. *Ipomœa Pes-Capræ* (Sweet). Western and southern shores of the island, very common.

105. *Ipomœa sagittifolia* (B.R.). (Mr. W. T. Féay.) Rare.

106. *Ipomœa triloba* (L.). Not frequent.

107. *Ipomœa Bona nox* (L.). Abundant but local, flowering in the evening. One of the most beautiful climbing plants known, its pure white corolla being salver-shaped, and perfectly flat, the tube being extremely long, and pale greenish white. The flower fades at dawn.

108. *Jacquemontia violacea* (Chois.). Flowers small, sky blue. Twining over shrubs, principally Lantana, common in the South portion of Key West.

109. *Dichondra repens* (Forst).

SOLANACEÆ

110. *Solanum nigrum* (L.). A small-leaved form.

111. *Solanum verbascifolium* (L.) A tall shrubby plant with heavy leaves and white flowers. Very common in the S.W. region.

112. *Solanum Bahamense* (L.).

113. *Solanum Blodgettii* (Chapman).

114. **Solanum Lycopersicum* (L.). Tomato. Waste places.

115. *Capsicum frutescens* (L.). Not uncommon.

116. *Physalis pubescens* (L.).

117. *Physalis angulata* (L.).

118. *Lycium Carolinianum* (Nichaux). Abundant in the salt marshes.

119.**Cestrum fastigiatum* (Jacq.) Very common all round the S.W. portion of the island. Not included in Chapman's Flora.

120. *Datura Tatula* (W.). A weed.

GENTIANACEÆ.

121. *Eustoma exaltatum* (Griseb). By the battery, north shore. 3 feet high, flowers very dark blue. A very beautiful plant.

APOCYNACEÆ.

122. *Echites umbellata* (Jacq.). Not uncommon.

123. *Echites Andrewsii* (Chapman). (Mr. W. T. Féay). Rare.

124. *Vinca Rosea.* (L.) All round the island; in waste places with Ricinus, Ambrosia, and Argemone Mexicana.

125. *Vallesia chioccoïdes* (Kunth.) = V. glabra (Cav.) Very rare; only one shrub observed.

126.**Thevetia neriifolia* (Juss) = Cerbera Thevetia. (L.) Naturalised near the town. Exceedingly poisonous, c.f. Kingsley's 'At Last' for a description.

ASCLEPIADEÆ.

127. *Asclepias Curassavica.* (L.) Waste places.

128. *Metastelma Schlectendalii.* (Dec.) A twining creeper.

129. *Seutera maritima.* (Reich). By the salt pans. Very abundant in one place only.

130. *Cynoctonum scoparium.* (Meyer.)

131. *Sarcostemma crassifolium.* (Dur.) (Mr. W. T. Féay.)

NYCTAGINEÆ.

132.**Mirabilis Jalapa.* (L.) In one place towards the N. shore; very likely an outcast from cultivation.

133. *Boerhaavia viscosa.* (Lag.) Common.

134. *Pisonia aculeata.* (L.) Extremely abundant, its greenish flowers proving very attractive to insect life. The thorns on the branches and the recurved spines of the fruit are great impediments to comfort in the "bush."

PHYTOLACCACEÆ.

135. *Rivina humilis* (L.). Common, and striking from its scarlet fruit.

136.* *Phytolacca decandra* (L.). Occasionally on waste ground. Adv. from the Southern States of America.

CHENOPODIACEÆ.

137.* *Chenopodum Anthelminticum* (L.). Naturalized from the States, one plant.

138. *Obione arenaria* (Moquin).

139. *Chenopodina maritima* (Moquin).

140. *Salicornia ambigua* (Michaux). By the salt pans, with the preceding.

AMARANTACEÆ.

141. *Celosia paniculata* (L.). W. shore. Common.

142.* *Amarantus hybridus* (L.). Adv. from U.S.A.

143.* *Amarantus albus* (L.). Adv. from U.S.A.

144. *Amarantus spinosus* (L.).

145. *Iresine vermicularis* (Mogim).

146. *Alternanthera Achyrantha* (R. Br.).

147. *Telanthera Floridana* (Chapman).

POLYGONACEÆ.

148. *Coccoloba uvifera* (Jay). S. shores. Common. 'The Sea Grape.'

EUPHORBIACEÆ.

149. *Euphorbia cyathophora* (Jay) var. graminifolia (Michx.) = E. heterophylla (L.). Abundant in many places. Easily recognized by the uppermost leaves being deep scarlet at the base, and bearing therefore some slight resemblance to a small and narrow-leaved Poinsettia.

150. *Euphorbia glabella* (Swartz).

151. *Euphorbia hypericifolia* (L.). Sea shore, in sand, common.

152. *Euphorbia maculata* (L.). Abundant in paths and everywhere.

153. *Euphorbia inæquilatera* (Sond).

154. *Hippomane Mancinella* (L.). (Mr. W. T. Féay.)

155. *Acalypha corchorifolia* (Willd.).

156. *Croton balsamiferum* (Willd.). Very common in the south portion of the island only.

157. *Aphora Blodgettii* (Torrey.). (Mr. W. T. Féay.)

158.**Ricinus communis* (L.). Everywhere.

BATIDACEÆ.

159. *Batis maritima* (L.) Salt marshes.

URTICACEÆ.

160. *Pilea hernarioïdes* (Lindley). Very abundant; a very small, fragile plant.

PALMÆ.

161.**Cocos nucifera* (L.). Naturalized in the northern portion of the island; common. The True Cocoanut Palm.

POTOMACEÆ.

162. *Halophila ovalis* (Hook), or allied sp. Quite fresh specimens floating in sea, after gale, 15th March, 1872.

ALISMACEÆ.

162A. *Echinocarpus radiatus* (L.) Around a small pond in the interior of the Island.

ORCHIDACEÆ.

163. *Epidendrum venosum* (Lindley.) N. part of the island, on trees (Mr. W. T. Féay).

AMARYLLIDACEÆ.

164.**Agave Americana.* (L.) Forming impenetrable hedges in the N. portion of the island.

BROMELIACEÆ.

165. *Tillandsia bulbosa* (Hooker). (Mr. W. T. Féay.)

166.**Ananassa sativa* (Lindley). Occasionally escapes from cultivation.

MUSACEÆ.

167.* *Musa sapientum.* (L.) The Banana is extensively planted, and is sometimes found apparently naturalized.

168.**M. Paradisiaca.* (L.) Ditto.

CYPERACEÆ.

Of this order I found 5 species of Cyperus, including C. Confertus (S.W.) and C. fuligineus (Chapm.), the others not yet determined, as they are in fragmentary condition, and also an Eleocharis, sp. incert.

Of Gramineæ about 10 to 12 specimens, including Eragrastis ciliaris (Link.); Panicum, 2 species; the abundant Dactyloctenium Ægyptiacum (Willd.) and Eleusine Indica (Gærtn.) and Cenchrus tribuloïdes (L.). The curious creeping Monanthochlöe littoralis (Englemann) also occurred on the southern sandy shores.

Only one Fern, that being Aspidium patens (Sw.), but Mr. Féay noted Acrostichum aureum (L.) and Anemia adiantifolia (L.) as well.

A Chara occurred plentifully in a pond toward the south portion of the island.

Dr. ALCOCK read some notes on Frog Tadpoles, illustrated by drawings. He said the life of the tadpole may be divided into periods, each characterised by the developments which take place in it. He described the first and second periods, leaving the remainder to be treated of in a future paper.

The first period extends from the deposition of the ovum to the escape of the young tadpole from the egg membrane. In our climate this occupies about a fortnight, the first week being spent in the segmentation of the yolk, the second in the development of the embryo. In a mass of frog spawn, however, the ova on the surface hatch first, and are followed by the others in succession to the centre of the mass, so that there is a difference of about a week between the earliest and the latest. The structures which have been developed when the embryo escapes from the egg are the cerebro-spinal axis and its supporting skeleton, with the continuation of these structures in the tail, the enclosing body-wall, rudimentary organs of sense, the visceral arches, the oral aperture and the cavity of the mouth, the heart, and the blood vessels of the developing parts; but the cavity of the abdomen remains filled with undifferentiated yolk-mass, and no commencement of the organs which it afterwards contains is yet made. Two other organs, however, have been formed, the use of which is temporary, and confined to the second period; these are the sucker and the external gills, and they are already so far developed as to be perfectly efficient when the tadpole escapes. The sucker is at first large and single, extending across the middle line, and it is in this condition when the animal is hatched. The external gills, two on each side, have attained such a size as to serve at once as organs of respiration.

The second period extends from the time of hatching to the completion of the mouth and alimentary canal, and the commencement of feeding; it, like the first period, occupies about a fortnight. The special temporary organs now in use are the sucker, which soon divides into two, and the external gills. The developments which take place are those of the bronchial arches and clefts; the internal gills; the eyes; the gill-chambers, formed by the opercular fold, which begins to grow on the second day and is completed on the fourteenth; the passages of the nostrils to the back of the mouth, these being in connection with the internal gills, the ciliary action of which draws water through them; and the suctorial, beaked mouth and coiled alimentary canal, peculiar to the tadpole.

This second period is a continuation of the embryonic condition; contact with water and aquatic respiration are necessary for further development, but rest is also required, and the animal continues as stationary as whilst in the egg. It is blind and helpless, and cannot feed, having no alimentary canal. Immediately on its escape the tail is used, but only to swim to some fixed object to which it attaches itself by its sucker, and there it remains till the close of the period, unless forcibly detached, when it at once refixes itself.

The suckers, though efficient almost to the end of the period, daily diminish in size and have disappeared at its close. The external gills attain their full size on the second day, after which they gradually shrink, but continue in action about a week, soon after which what remains of them disappears within the opercular fold. The organs which are developed during this period are all completed at about the same time, that is, very nearly at its close. The eyes and nostrils progress regularly from the time of hatching, but with regard to the internal gills and the alimentary canal, it appears that the former are commenced first and are probably in use about the fifth or sixth day in conjunction with the external gills, gradually increasing in efficiency as the latter diminish in size, but the complete apparatus for the tadpole respiration is not perfected until the opercular fold has joined the skin of the abdomen, leaving only a small opening at the left side, and until, in conjunction with the chambers thus formed, the nasal passages are opened into the back of the mouth. The development of the peculiar tadpole mouth and the enlargement of the abdomen, indicating the formation of the coiled intestine, commences only when the gill-chambers are complete, and these structures are formed and brought into use within the last three days of the period; during which time also the tadpole becomes beautiful with spangles exactly resembling bits of gold leaf embedded in the rich brown transparent skin.

Ordinary Meeting, April 4th, 1882.

R. ANGUS SMITH, Ph.D., LL.D., F.R.S., &c., in the Chair.

"On the Occurrence of Oxide of Manganese (Wad) in the Yoredale Rocks of East Cheshire," by ARTHUR SMITH WOODWARD, Student of Owens College. Communicated by Dr. CHARLES A. BURGHARDT.

I.—*Introduction.*

One of the most noticeable geological features of the eastern part of Cheshire is the enormous fracture forming the boundary between the carboniferous and new red sandstone formations, and known as the Red Rock Fault. This fault has a direction N.E. and S.W., and, according to the Memoirs of the Geological Survey, extends from a little to the N. of Stockport to Talk o' th' Hill, in Staffordshire, a distance of about 30 miles. In the more northern part of its course superficial evidence of its existence is either exceedingly scanty or entirely wanting, owing to the thickness of the glacial drift deposits which characterise the district through which it passes; but as it approaches Macclesfield there are slight indications at the surface of its presence, and as it continues south of this town the superficial evidence gradually becomes greater and more definite. Here there are considerable eminences on the western side of it, consisting of triassic strata not obscured by glacial drift, and hence the fault itself becomes visible at the surface.

Between Poynton and a locality about three miles south of Macclesfield it is bounded on its eastern side by the carboniferous formations in succession,—the two lower divisions of the coal measures being most northern, next five divisions of the millstone grits, and below these, more to the south, the

Yoredale Rocks,—and it is in the latter rocks that the greatest amount of disturbance has arisen from it, in consequence of the fact that they are constituted not of thick, compact masses of sandstone, but of comparatively thin beds alternating with bands of shale. In this locality, in and around Ratcliffe Wood, there is a large number of sections, both natural and artificial, extending for several hundred yards to the eastern side of the fault, and after examining them and taking note of the dip in each case, it is easily seen that the greatest confusion exists among the strata; small faults are very numerous, and often prove themselves to be great obstacles to the quarrying operations there carried on; and contortions of the beds, varying from only two or three feet to several yards in extent, abound in all directions. It is in the fissures produced by the disturbance of the beds in this locality that the mineral which I intend to describe in this paper is found.

II.—*Description of Section.*

The quarrying at Ratcliffe Wood is carried on chiefly in tunnels, formed by the excavation of the beds of rock which are best adapted for the purposes to which the stone is applied, namely, repairing and making roads. Some months ago the quarrymen met with a fault, which cut off the bed of rock that they were following, and in attempting to find again this lost stratum on the other side of the hill they opened a section nearer to the Red Rock Fault; and it was here that I first noticed the oxide of manganese, early in December last.

This is the nearest section to the fault now exposed in that locality—with the exception of comparatively unimportant exposures in the brooks running through the wood—and is probably not more than 30 or 40 yards from it. As this is a very interesting section, apart from its mineral characteristics, since it shows the effect of the force exerted during the production of the great fault, a somewhat brief description of it may, perhaps, be not out of place at this point.

The principal opening is about 30 feet in length and 20 feet in height, but from the other small sections around it, many more details of the stratification can be obtained. The direction of all these sections is nearly at right angles to the fault, namely, E. and W.

The lowest bed exposed consists of variegated soft shale, in small flakes (dip 59°—10° E. of N.); above this is a stratum of sandstone, 5 feet in thickness, containing abundance of MnO_2 in the many fissures which traverse it, and it is a noticeable fact, that in the lower portion of the section there is a larger quantity of the mineral than in the upper portion; next is a bed of variegated soft shale, 7 feet in thickness, in flakes, and similar in nature to the bed underlying the sandstone previously mentioned; the remainder of the section consists of alternating bands of shale and sandstone, much broken and contorted, and 14 feet thick, which gradually become more and more bent until they reach a position nearly five feet above the underlying bed of shale, when a stratum of sandstone, 8 inches thick, undergoes three decided bends—in one case, a complete break. This sandstone, like all the other beds in the section, has been shattered into small angular fragments, and into the cracks thus formed mineral matter has been introduced by the percolation of water. Many of the smaller fragments have again been cemented together by oxide of iron, as the cracks surrounding them had not separated the adjoining portions of rock far asunder, while the walls of the larger fissures are *only coated* with oxide of iron and argillaceous matter, or, in the upper part of the section, with oxide of manganese, and are not firmly united together.

Above this contorted bed of sandstone, the alternating layers of rock are similarly disturbed for a thickness of about 7 feet, when the arrangement of the beds becomes very obscure, and a little above this the series assumes a nearly vertical dip.

The general appearance of the section shows that the contortions of the series have been produced by a slip, most probably at the time when the Red Rock Fault was formed. This is evident not only from the disturbed beds lying between two series, which have been very little bent, but also from the peculiar appearance of the layer of shale beneath, and the confused mass of broken sandstone above. In the underlying shale there are two or three very thin seams of carbonaceous matter, which are rendered rather conspicuous by their dark colour; these are curiously contorted, having been completely twisted in no less than four places, the interior of the folds being occupied by confused masses of variously coloured crushed shale.

III.—*Occurrence and Properties of the* MnO_2.

The most typical specimens of oxide of manganese (wad) are to be obtained from the fissures in the lower bed of sandstone in the section just described. Here it occurs in considerable quantity, and is in a very accessible place. The walls of the cavities produced by the fissuring of the rock are covered with a layer of the mineral, never more than $\frac{1}{4}$ inch in thickness, which is not at all smooth on the exterior, but has the appearance of soot adhering to the side of a chimney; this form is caused by a pellet-like structure assumed by the substance. The layer appears to cover all the walls of the cavities equally, not becoming perceptibly thicker on the lower sides, and not altering in appearance in different parts.

But the most peculiar and characteristic feature of the wad in this sandstone is its occurrence in miniature columns, joining the two opposite walls of the cavities, and in long slender threads, stretching in all directions over the rough surface of the mineral-incrustation. So far as I have been able to ascertain, none of these columns or threads are perfectly solid but are all pierced longitudinally by a canal, which is often situated not quite in the centre; in some cases this is so large that the surrounding oxide of manganese becomes very thin and a delicate tube is formed, while in many specimens the calibre is so small that the perforation can only be seen on close examination. The columns and threads are not all straight, but many are bent in various directions and not unfrequently branched—the axial canals in all cases being preserved throughout the bifurcations.

These interesting structures in external appearance are rough and dull, but cross-sections exhibit a very distinct resinous lustre. The size of the columns is not great, their diameter never exceeding $\frac{1}{8}$th of an inch, and their length being seldom much more than one inch; the tubular threads are sometimes four or five inches long, but their diameter is very much less than that of the columns, few of them having a section greater than $\frac{1}{20}$ inch across.

To account for the formation of these columns and threads appears, at first sight, a somewhat difficult matter, but after carefully taking into consideration the position of the mineral and the nature of its surroundings, an explanation is afforded which has been definitely proved to be correct by Mr. Dale, of Macclesfield.

The position which the greater part of the oxide of manganese occupies is about 14 feet from the surface, a depth to which the roots and rootlets of the surrounding wood are able to penetrate by means of the numerous cracks in the strata. Rootlets are to be seen in the fissures in many parts of the section, and in those which are lined with oxide of manganese they are especially abundant. They stretch across the cavities, and traverse the surface of the black mineral in all directions; and after closely searching for some time, it is possible to find specimens to illustrate all stages of the conversion of these organic bodies into columns and threads of oxide of manganese.

Many of the rootlets, probably in their first stages of decomposition, have assumed a reddish or unnatural brownish colour; others, in a later stage, exhibit minute patches of the black oxide studding their surface, appearing as if affected by a black mildew; others are almost entirely covered with the incrusting mineral; while, in the final stage, the whole of the organic matter has disappeared. In short, the rootlets are completely pseudomorphosed into hydrated dioxide of manganese by the action of the decomposing plant tissue upon a solution of some manganese salt.

These facts are interesting as showing that the deposition of oxide of manganese is still taking place, or, at least, did take place until the section was opened. There is now no perceptible percolating water, even in the most rainy weather, but the mineral is at all times moist.

With regard to these oxide of manganese pseudomorphs, it appears that very few cases of the alteration of organic matter into this mineral have been recorded. This oxide is not mentioned in Phillips' Mineralogy,* in the list of minerals said to occur as petrifactions, but is referred to in the "Erster Nachtrag zu den Pseudomorphosen," by Blum. Wiser has described a fossil consisting of black oxide of manganese, which he stated, in 1842,† to be the first instance on record of this mineral occurring in a petrifaction; and again, in 1851,|| he mentioned a fragment of an Ammonite from Gonzen, near Sargans (Switzerland), which was fossilized in the same manner. Neither of these cases, however, can be regarded as quite similar to the pseudomorphism of the rootlets, since it was not the truly organic matter that was mineralised, but the surrounding chiefly-inorganic shell.

The mineral itself, as found in the bed of rock in the section at Ratcliffe Wood already described, is of a bluish-black colour when freshly obtained, but assumes a browner

* Edit. Brooke & Miller, 1852.

† Jahrbuch für Mineralogie, &c. || Ibid.

tint on exposure: its hardness is less than 1. It is easily crushed into powder between the fingers, and has a characteristic crispness. When heated in a closed tube water is evolved, and under the blowpipe it is infusible. Its streak is of a dark yellowish-brown colour.

A quantitative analysis of the mineral gave the following as its percentage composition:—

$$
\begin{aligned}
MnO_2 &= 33{\cdot}634 \\
Fe_2O_3 &= 9{\cdot}375 \\
Al_2O_3 &= 22{\cdot}913 \\
SiO_2 &= 16{\cdot}815 \\
\text{Water} &= 17{\cdot}237 \\
\hline
& 99{\cdot}974
\end{aligned}
$$

This analysis probably does not show the exact composition of the pure mineral, since it is almost impossible to obtain a sufficient quantity entirely free from the surrounding argillaceous matter.

IV.—*Distribution of* MnO_2 *in Ratcliffe Wood.*

So far as I am yet aware, there is only one other spot in Ratcliffe Wood where oxide of manganese is to be seen occurring in the same form as the mineral in the section previously described. This is a few hundred yards to the east of the latter, and the deposit exhibits not only the same peculiarities but others which render it even more interesting. Here, as in the previously mentioned case, the mineral occurs both as an incrustation and pseudomorphic after rootlets; but it is also in many parts covered with a thin layer of a white, translucent, crystalline mineral—a highly hydrated phosphate of alumina with a proportion of silicate—which, besides, mineralizes rootlets in an analogous manner to the oxide of manganese.

In this same section, too, there is exposed a lenticular mass, 4ft. 6in. long and 3in. in greatest thickness, which is black, earthy, and moist, and evolves chlorine on treatment with hydrochloric acid. It is situated in the midst of shales, and most of the small fissures for some distance beneath it are filled with black oxide of manganese.

The oxide of manganese occurs in many other fissures in and around Ratcliffe Wood, but nowhere so abundantly as in the sections referred to in this paper. The most widely spread form is a thin black film, not sufficiently thick to exhibit to the unassisted eye any pellet-like structure, as is the case with the mineral described above. Such a film is to be seen in some of the fissures in almost every section in the wood, and the fact that the oxide does not occur in larger quantities cannot be owing to the circumstance that there are no cracks exposed so large as those in which it is found in pellets, miniature columns, and threads, but in consequence of its scarcity in the stratum from whence it was derived; for in one quarry there are two faults which produce cavities and fissures of a much larger size, and yet these are well filled with brown iron ore with a comparatively small amount of MnO_2.

In the Triassic strata, on the E. side of the Red Rock Fault, this mineral occurs not only as an infiltration-product, but also as a part of the cementing material of certain thin beds of the sandstone.

V.—*References to Descriptions of Deposits of Hydrated* MnO_2.

On referring to Bischoff's "Chemical Geology"* an enumeration of instances recorded before 1854 of the occurrence of deposits of hydrated oxide of manganese is to be found. Here no less than six cases are mentioned.

During the repair in 1840† of a water channel hewn in the rock in the neighbourhood of Nürnberg, an immense mass of hydrated oxide of manganese was discovered. A spring near the Cape of Good Hope, whose waters have a temperature of 110°F., is said to deposit in the discharge

* Vol. I., pp. 160, 161, Edit. 1854. † Journal für prakt. Chem., Vol. 21.

channel a very thick incrustation of the same mineral, extending to some distance from the spring.* A mineral spring at Carlsbad, depositing a mass resembling manganite, has been described by Kersten. Braconnet examined and described in 1821† a precipitate of oxide of manganese found in the outlets of the springs of Luxeuil. A deposit of the same mineral from the water in a mine at Freiberg has been analysed by Kersten and described in the "Archives für Mineralogie, &c." (Vol. 16), and in this journal, also, Nögerrath has given an account of the nature and occurrence of the manganese ores in the Hundsrück, and in Soonwald, on the left bank of the Rhine.

VI.—*Associated Minerals.*

The most important minerals associated with the oxide of manganese in the strata of Ratcliffe Wood, besides the phosphate of alumina already mentioned, are brown iron ore, calc spar, pearl spar, iron pyrites, and zinc blende. The brown iron ore occurs in thin incrustations, in fibrous stalactitic masses, and in hollow spheres which have, especially on the inner side, a very peculiar lustre. The calcite occurs in a crystalline state in small fissures in almost every section, and is found crystallized occasionally in the form—$\frac{1}{2}$R. and the combination—$\frac{1}{2}$ R. 16R. The pearl spar occurs in many fissures beautifully crystallized in the form —$\frac{1}{2}$R; it is tinged with oxide of iron, and the crystal faces are bent in the characteristic manner. Iron pyrites occurs abundantly, often perfectly crystallized; and zinc blende is found in small masses scattered among the crystals of calcite and pearl spar.

VII.—*Conclusion.*

Oxide of manganese occurs in many places in the other Yoredale strata of the district, but nearly always in very small quantities. It also occurs widely spread throughout the overlying Millstone Grits; in these strata it forms

* L'Institut, 1844. † Ann. de Chim. et de Phys., 1821.

dendritic markings radiating from the fissures in the rock, and constitutes a portion of the cementing material in many of the concretions.

In the sandstones of the coal measures, also, oxide of manganese forms part of the cementing material in many of the concretionary structures.

In fact, careful observations would probably show that oxide of manganese is quite as widely distributed as oxide of iron, the only difference being that the former mineral generally occurs in defined patches and in comparatively small quantities. The distributing causes seem to have acted as universally with the one mineral as with the other, but in the case of the manganese only small amounts were concerned, while in the case of the iron there was an almost unlimited supply.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

March 13th, 1882.

Alfred Brothers, F.R.A.S., President of the Section, in the Chair.

Mr. Theodore Sington, of Victoria Road, Rusholme, was elected an Associate of the Section.

Mr. Marcus M. Hartog, B.Sc., F.L.S., made a communication upon Water Fleas.

"On Cyprœa Guttata (Gmel.)," by J. Cosmo Melvill, F.L.S.

This shell has been for the last two hundred or more years esteemed as one of the most choice and rare in existence. It is strange that even in these days it is almost unique, and in company with another shell of the same genus (Cyprœa princeps (Brod.), from the Persian Gulf), and the far-famed Conus gloria maris (Chem.), always commands a higher price than any other shells.

There are but three Cyprœa princeps known, two of which are in our national collection, which also boasts of the unique C. leucodon (Brod.), while there are twelve or thirteen of the Conus gloria maris. Allowing therefore for the Cyprœa princeps and leucodon at present to hold the first post of honour, the Cyprœa guttata, the subject of this notice, will stand next in degree of rarity, there being but six known, viz., the specimen now exhibited, from my collection, one in the British Museum, two in the famous collection of Miss Saul, of Bow, near London, one in the Leyden Museum, and one, not in very good condition, in that of Dr. Prevost, of Alençon.

This cowry, the nearest approach to which is found in the small and common C. erosa (L.) of Indian seas, is so abundantly distinct from any other as to put all Darwinian laws of evolution at defiance. It is chiefly characterized from others of the same group in the subgenus Luponia by being larger—2½ inches long—of lighter build, and above all by the sulcate grooves at the base, the teeth being well developed on both sides, and of a dark orange red, extending round the base of the shell in continuous furrows.

It is reported, but on insufficient evidence, to be a native of China. No specimen is known by Europeans to be in the possession of any inhabitant of that, or in fact of any extra-European, country. There is certainly no specimen in any collection in the United States.

It is probably an inhabitant of deep water. The shell is very light and fragile. No specimen however in fragmentary condition has been known to have been observed.

This particular specimen, which is said to be the finest of the six in existence, I obtained through the agency of Mr. Damon, from Mr. Hugh Owen's collection, where it had been located over twenty years, having previously been in the cabinet of M. de Verreaux.

"Lepidoptera of the Shetland Islands," by HASTINGS C. DENT, C.E.

I thought it might interest the members to see a few of the Lepidoptera of Shetland Islands, and have brought some which I obtained recently. In *Entomologist*, Nov. and Dec., 1880, and Oct. and Dec., 1881, will be found full accounts of these insects, so I do not purpose to do more than call attention to two or three points.

Hepialus humuli var. Hethlandica. I am unfortunately unable to show you this insect, being unable to procure specimens, but I exhibit a plate showing some of the principal remarkably aberrant forms of this, the common Ghost Moth.

Hepialus velleda. Exclusively a northern insect in the British Isles. The Shetland form is far more distinctly and beautifully marked than the ordinary type. In the south it is always a mountain insect, and is found in the Pyrenees and Altai mountains.

Larentia caesiata. Abundant in the N. Counties of England. I took it last year near the summit of Sca Fell Pike. The Shetland form is much darker than the English or Scotch type.

Emmelina albulata. The Hebrides form is very distinct, and has been named var. *Hebudium.* The Shetland form is named var. *Thules.* Both varieties vary much in the colouring and marking.

Melanippe hastata. The English and European forms are very similar. The Shetland form is smaller and much more beautiful. There is a row of black spots along the centres of the wings which are not developed in any of the typical form. The Shetland form is an intermediate between Melan. hastata and the Icelandic species M. hastulata. (In *Entomologist* for Jan., 1881, is a beautiful var. of M. hastulata.)

Camptogramma bilineata. The common Shell Moth. This common moth is exceedingly variable in its markings, some specimens being much darker than others, but I have seen none taken in England which approach the Shetland form in the distinct and beautiful dark tints.

Xylophasia polyodon. This is an abundant and very variable species. I exhibit one specimen of the ordinary type of a beautiful brown variety, taken by Mr. Melvill, at Prestwich. But the Shetland form is distinctly *black*, and I have seen an immense number of this black variety, and am informed that the collector had not found one of the typical form in the Shetland Islands.

Charœas graminis. The Antler Moth. The only species of this genus, very widely distributed in Central and Northern Europe, and North Asia; this is the insect which appeared in such alarming abundance in the neighbourhood of Clitheroe or Pendle Hill last year. I succeeded in rearing from some larva I took at that time, some very light-coloured specimens. The Shetland form is a much more beautifully marked insect.

Mamestra furva. A local insect often confounded with commoner species. The Shetland form is rather darker.

Anarta melanopa. In the British Isles this is exclusively a northern insect. It will be seen that while the Scotch form is *brown*, the Shetland var. is distinctly *black.*

I have reserved *Pyrameis* (*Vanessa*) *Cardui,* the Painted Lady, to the last, as I wish to enter somewhat more into detail respecting it. This is one of the three butterflies which are alone recorded from the Shetland Islands. The other two are P. Atalanta, and Cænonympha Typhon, or Davus.

Cænonympha Typhon, or *Davus,* is a north country insect, though it is found in Ireland, but not in the Isle of Man. It occurs on the Scotch mountains at a height of 2000ft. above the sea level. I have taken the var. Rothliebii on Chat Moss, and in Delamere forest. The Shetland form does not differ from the typical *C. Davus.*

Pyrameis Cardui is *the* one of the 64 British butterflies that occurs all over the world except in S. America. It is perhaps the least varied of all species. I exhibit specimens from England, Shetland, Europe, Cape of Good Hope, and India. It is also found unchanged near Hudson's Bay, while P. Atalanta varies slightly at that locality.

P. Cardui and P. Atalanta are frequently found in the same localities, and I exhibit specimens from England and

North America. Now, P. Cardui is found in India, but P. Atalanta is *not*, but instead of it we find there is a species which is termed P. Indica vel Callirhöe, of which I exhibit a specimen. This insect appears to be an intermediate form between Cardui and Atalanta. In the upper side of *Indica*, the insect is substantially Atalanta, while the lower portions of the wings bear a resemblance to Cardui. In the under side, the upper portions of the upper wings are similar to Atalanta, and the lower to Cardui, and in the lower wings the upper portion resembles Cardui, and the lower Atalanta. It would be extremely interesting to try whether a cross could be obtained resembling Indica, by breeding Cardui with Atalanta for a few generations. In the free state the Cardui and Atalanta are generally found together, yet no intermediate is discoverable co-existent. P. Cardui is a curious insect in the manner of its appearances. Some years it is so exceedingly abundant as to become a pest, while probably the next year hardly a specimen is to be found in that locality. It is to be found near the sea coast, and in all places up to the summits of Ben Lawers and Snowdon.

Though much has been done towards elucidating many problems of geographical distribution, there is still much to be explained. For instance, in the Isle of Man there are 16 of the 64 British species of butterflies. They none of them present any difference from the English forms except one, the Vanena Urticæ, small tortoise shell. When I was in the Isle of Man, in 1879, I took a remarkably small specimen of that insect, and on showing it to Mr. Edwin Birchall, he informed me that this small variety is the only form of V. Urticæ taken in the Island, and very kindly presented me with a series.

In conclusion, I must express my best thanks to Mr. Melvill, who most kindly placed his large collection at my disposal to select any insects that I wished, for the purpose of comparison with the Shetland and Hebrides forms.

"Notes on the Giant Dragon's-blood Tree at Orotava," by Mr. John Plant, F.G.S.

Last August, as my friend, Mr. John Higgin, was on his return from the Philippines to visit old England once more, he made a detour from Lisbon to the Canary Islands to see the cochineal plantations as well as the physical wonders at Teneriffe. He made a pilgrimage to Orotava, to behold for himself the renowned patriarchal Dragon-tree, which in one spot had survived 6000 years of mundane changes all around, only to find every vestige of its existence swept away—fifteen years before it had been broken down in a great gale. A good part of it had gone for dye-wood, the chips and fragments had been burnt, and visitors had carried off the remainder. He offered inducements to the natives, and the ground upon which the old tree had stood was dug into and several pieces of the bark were found, three of which I have now to bring before you as the very last remains of the old giant of Orotava.

The Canary Islands were known to history in the year 1330, and the tree in 1402. In 1493 Alonzo del Lugo claimed the islands under the Spanish authority. He relates that this hollow Dragon-tree was in use by the Guanche Indians as a temple for heathen rites, but that he reformed such practices and made it into a chapel for holy mass. Other Spanish historians and voyagers have left records of visits to Orotava in succeeding centuries, which it is not necessary to reproduce here, except in the instance of Baron Von Humboldt, who visited the Canaries in June, 1799, when on his first journey for exploration in Central and South America.

His narrative of this visit runs: "Although we had been made acquainted from the narrative of many travellers with the Dragon-tree of the garden of M. Franqui, we were not the less struck with its enormous magnitude. We were told that the trunk of this tree, which is mentioned in very ancient documents, was as gigantic in the 15th century as it is at the present time. Its height appeared to be 50 or 60 feet, its circumference, near the root, 45 feet, but Sir G. Staunton, who was at Orotava in October, 1792, found that at ten feet from the ground the girth of the trunk was 36 feet, which corresponds perfectly with the statement of Borda in 1600."

"The trunk (says Humboldt) is divided into a great number of branches which rise in the form of a candelabrum, and are terminated by tufts of leaves like the Agucca. The tree still bears flowers and fruit every year. The Dracæna presents a curious phenomenon with respect to the migration of plants. It has never been found in a wild state in Africa; the East Indies is its real country. How has it been transplanted to Teneriffe? Does its existence prove that at some distant period the Guanches had connexions with other nations originally from Asia?"

Humboldt gives an engraving of the famous Dragon-tree in his "Atlas Pittoresque," but it appears that it was supplied from a drawing sent him by M. Marchais, and that from an earlier sketch by M. Ozone, and the result, as Piazzi Smyth puts it, "was a gradual growth of error and conventionality, as man copies from man," and there does not exist in any of the popular botanical works a truthful drawing of this extraordinary floral form, which belongs to the natural order Liliaceæ.

The course of the history of this Dragon-tree since the time of Humboldt's visit, as far as I can trace it through the works of travellers, appears to consist of records of its successive mutilations from frequent destructive storms and the carrying away of pieces by visitors from every land. In 1819 a great gale wrenched off a large arm; in 1829 a deluge of rain fell upon the Peak and sweeping down through Orotava, carried off nearly one half of the old hollow trunk, and C. Piazzi Smyth records "that certain Goths hacked an immense piece out of the thin wall of the hollow trunk for the Museum of Botany at Kew." In place of growing larger in later years, the old tree was rapidly collapsing, when the Marquis of Sanzal came into possession of the Villa de Orotava, upon whose grounds the Dragon-tree stood. The Marquis at once put a stop to all depredation, and prohibited any pieces of the tree from being carried off by visitors. He further endeavoured to supply the abstracted portions of the trunk with masonry, trying thus to give a further chance of renewed life and vigour; for a few years these efforts had their reward, the veteran became the lion for all modern visitors to mount the steep and gaze at with pleasure and wonder.

When C. Piazzi Smyth went on his astronomical inquiries in the Canaries in 1856, twenty-six years ago, he had leisure and opportunity for a careful examination of the old Dragon-tree, the results of which are charmingly told in his chapter on Dracæna Draco: "Teneriffe, an Astronomical Experiment, by C. Piazzi Smyth, 1858, p. 800." Above all, he was able to take several photographs of the old tree, as well as of younger and more normal specimens of the Dracæna. He describes the perilous state of the old tree from the unequal level of the ground, and says it was nearly smothered about the trunk with laurels, oranges, peach, and other trees, and a rivulet—at times a torrent—flowed along its front. It had been known by the natives as a landmark betwixt properties adjoining for centuries. He measured it as 60 feet high and $48\frac{1}{2}$ feet circumference at that height, it was 28·8 feet circumference at the part where the branches spring out from the trunk, and at 6 feet from the ground was 35 feet 6 inches in circumference. But he says: "this is no proper tree with woody substance, it is merely a vegetable, an asparagus stalk of eminent slowness in growth, which has gained for it the credit of being the oldest tree in the world."

When the Dragon-tree is young, the simple stems are smooth, or marked only by shallow transverse indentations of foot stalks of past leaves. The compound stems are deeply corrugated longitudinally, and the trunk has an evident tendency to divide continually as it descends. When once a stem has branched its life seems to have departed, being replaced by the lives of the several young trees of its kind left growing on its summit, and whose roots, entering the bark and encasing the old stem on every side, conceal its slow withering corpse from the light of day. Ages pass by, the young trees flourishing, die in their turn, each producing two or more new trees mounted on their summits, and thus presenting such a surface to the wind, that the hollow base of the original tree would never be able, unless artificially assisted, to support the strain, and hence the true explanation of the hollow interior of the trunk from the remotest times in the past to the fatal autumnal day in 1867, when the great gale snapped asunder, for ever, the cords of life of one of the world's oldest inhabitants.

Mr. R. D. Darbishire, B.A., F.G.S., exhibited a fine series of Ceylonese land and fresh-water shells, procured through the instrumentality of Mr. M. M. Hartog, F.L.S.

The Helices were mostly of the Acavus section, which in Ceylon reaches its highest development. Conspicuous among these are the rare H. superba (Pfr.), H. Grevillei (Pfr.), H. Phœnix (Pfr.), and the curious little H. Skinnerei (Pfr.). The common H. hæmastoma (L.) was also abundantly represented in many beautiful varieties, and the curious Helix Rivolei (Pfr.) of the subgenus Polygyra was also worthy of comment.

The fresh-water shells were mostly Paludomi, which genus is endemic to Ceylon alone.

In the discussion which ensued, Mr. Melvill said that he possessed a specimen of a *reversed* Helix hæmastoma, believed by Mr. Sowerby to be the only one yet recorded in this state.

At the meeting of the Microscopical and Natural History Section, on the 13th February, 1882, Mr. Marcus Hartog, referring to his remarks "on the treatment of damaged india-rubber with a solution of magenta," on the 10th October, 1881, stated that Mr. William Thomson, of Manchester, was the discoverer of the application of magenta there recorded.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

Annual Meeting, April 17th, 1882.

Alfred Brothers, F.R.A.S., President of the Section, in the Chair.

The Secretary's Report and the Treasurer's Accounts were presented and passed.

The following gentlemen were elected Officers for the ensuing session 1882-1883.

President.

J. COSMO MELVILL, M.A., F.L.S.

Vice-Presidents.

A. BROTHERS, F.R.A.S.
R. D. DARBISHIRE, F.G.S.
JOSEPH BAXENDELL, F.R.A.S.

Treasurer.

MARK STIRRUP, F.G.S.

Secretary.

ROBT. E. CUNLIFFE.

Council.

THOS. ALCOCK, M.D.
CHAS. BAILEY, F.L.S.
JOHN BOYD.
HASTINGS C. DENT.
MARCUS M. HARTOG, B.Sc., F.L.S.
A. MILNES MARSHALL, F.L.S.
THOS. ROGERS.
W. C. WILLIAMSON, F.R.S.

Mr. Boyd remarked upon the discovery of the egg cases of Pediculis Capitis in the crevices in an African Chief's head stool in the possession of a friend of his.

Mr. Plant stated that he had endeavoured to obtain larger specimens of the Dreissena noted at the last meeting, but without success.

Dr. Alcock concluded his notes on Frog Tadpoles by describing the three remaining periods into which their life-history may be divided.

The third period extends from the thirtieth to the fiftieth day, and appears to be devoted entirely to growth, no new developments being observed. The tadpoles swim actively, feed voraciously, and grow very rapidly. During this period water continues to be taken in through the nostrils to supply the gills, and the opening by which it is discharged from the gill-chamber becomes tubular, extending upwards and backwards, embedded in the skin until it terminates in a short conical tube projecting from about the middle of the left side of the body. The mouth consists of a pair of strong, brown, horny beaks, with serrated edges, and is surrounded by a broad expanded sheet of white fleshy membrane, irregularly frilled and scolloped at its edges. Its inner or front surface is furnished with long rows of small brown teeth set upon white, apparently cartilaginous bands, so that they resemble combs. There are three sets of these combs on the upper and four on the lower lip. The alimentary canal in the abdomen consists of a long simple tube of equal diameter throughout, and about three and a half times the length of the tadpole; it is folded in half, and thus doubled, is coiled round and round, filling the left half of the abdominal cavity, and forming in its final coils the regular flat spiral seen on removing the skin of the ventral surface.

The fourth period extends from the fiftieth to the seventy-fourth day. Feeding is very active, and rapid growth continues. The developments which take place in it are those of the limbs, with the shoulder girdle and pelvis, and the lungs. Water no longer enters by the nostrils, but passes through the mouth. The pair of papillæ, seen on each side at the root of the tail as early as the thirtieth day, now begin to enlarge at their ends, become broader, and at length divisions marking the toes appear, at the same time the knee and ankle are indicated by bendings in the lengthening limbs. In fifteen days both fore and hind legs may be said to be fully formed, though the toes of the hind pair are still without webs. The development of the fore legs within the gill-chamber advances equally with the hind legs. At the close of the period both pairs are well grown, and the shoulder girdle and pelvis are developed. The lungs at the same time have attained a considerable size, and are in the form of a pair of sacculated tubes bluntly pointed at their free end.

The fifth and last period of the aquatic life of the frog extends from the seventy-fourth to the eighty-third day, at which time the animal has left the water and attained the perfect form of the adult. At the commencement of this period it is a tadpole with a large tail, a pair of large hind legs with webbed feet, and a pair of equally well developed fore legs still retained within the gill-chamber. The gills continue in action, and the opening at the left side remains for the discharge of water. But now remarkable changes rapidly take place. The animal ceases entirely to feed, and the alimentary canal soon becomes empty, the large white frilled lips shrink, and the sets of small teeth upon them degenerate and drop off, the horny beaks disappear, the mouth widens, the lips consist of ordinary skin, and the large fleshy bifurcated tongue of the frog is formed. At the same time, the intestine shrinks both in length and diameter, especially at the part which forms the centre of the coil; soon afterwards its upper part begins to be dilated to form the stomach, and the remainder becomes rapidly smaller and shorter as the stomach enlarges, until it consists of a small and slender gut, making only two or three short turns below the stomach at the left side. The liver at the same time enlarges, and the gall-bladder is seen, very large and filled with dark green bile.

When these changes in the alimentary apparatus have been partly accomplished, the forelegs are pushed out, the action being instantaneous for each limb, sometimes the right, sometimes the left comes out first, and the left limb is always forced through the gill-opening, the margin of which is torn in consequence of the size of the limb being too large to pass through the natural aperture. On the right side, the opening is usually a ragged rent in the skin, which has become thin at that part. The immediate consequence of the protension of the forelegs is to stop aquatic respiration and throw all the work of breathing on the lungs. The animal now remains almost constantly on the surface, and it very soon becomes exhausted and drowns if unable to support its mouth above water. The tail at this time rapidly shrinks, being absorbed and used as stored-up nutriment by the animal whilst it is unable to feed. It remains several days in the water in this state, but when the tail has been reduced to a brown stump of about half an inch long, and the changes in the alimentary canal are completed, the animal shows an instinctive desire to climb. Reaching the border of the pond it will make its way up a steep or even perpendicular surface to the height of several feet, if this be necessary, in order to climb the bank. The remaining stump of tail serves as provision for several days longer, after which the young frog takes small insects as food.

It must be remarked that no special value is attached to the exact number of days assigned to each period, for in strictness they apply only to the particular tadpoles examined. In order to make the successive periods agree as nearly as possible with each other, the most advanced tadpole was selected out of a number taken for each daily observation, and in consequence the periods are made rather shorter than the averages would have been. There was an interval of twenty days between the escape of the first and of the last frog from the water.

THE MICROSCOPICAL AND NATURAL HISTORY SECTION

OF THE

LITERARY AND PHILOSOPHICAL SOCIETY OF MANCHESTER,

IN ACCOUNT WITH T. H. BIRLEY, TREASURER.

Dr.

		£	s.	d.
1881.				
Nov. 10.—	To H. T. Stainton (Zoological Record)	1	0	0
1882.				
Feb. 7.—	,, J. Van Voorst (Ibis)	1	1	0
,, —	,, J.E. Cornish, (Micro. Journal to October)	1	2	6
Mar. 25.—	,, C. Bailey, (Challenger Reports, vols. I, II, and III)	5	0	0
,, —	,, Subscription to Parent Society	2	2	0
,, —	,, Postage, Tea, Coffee, &c.....................	4	5	9
,, 29.—	,, C. Simms & Co., (Circulars and Cards)	2	16	6
,, —	,, Balance in Manchester & Salford Bank	117	1	0
		£134	8	9

Cr.

		£	s.	d.
1881.				
April 8.—	By Balance in M. & S. Bank.....................	35	5	1
1882.				
Mar. 14.—	,, C. Bailey, Esq., from Parent Society ...	80	0	0
—	,, 37 Subscriptions at 10s........................	18	10	0
—	,, Interest allowed by Bank to Dec. 20, 1881	0	13	8
		£134	8	9

Examined and found correct,

April 17th, 1882,

HASTINGS C. DENT,

MARK STIRRUP.

List of Members and Associates, April 17th, 1882:

Members.

Alcock, Thomas, M.D.
Bailey, Charles, F.L.S.
Barratt, Walter Edward.
Barrow, John.
Baxendell, Joseph, F.R.A.S.
Becker, Wilfred, B.A.
Bickham, Spencer H., Jun.
Birley, Thomas Hornby.
Boyd, John.
Brogden, Henry.
Brothers, Alfred, F.R.A.S.
Cottam, Samuel.
Coward, Edward.
Coward, Thomas.
Cunliffe, Robert Ellis.
Dale, John, F.C.S.
Dancer, Jno. Benjamin, F.R.A.S.
Dent, Hastings Charles.
Darbishire, R. D., B.A., F.G.S.
Dawkins, W. Boyd, F.R.S., F.G.S.
Deane, W. K.
Higgin, James, F.C.S.
Hurst, Henry Alexander.
Marshall, A. Milnes, F.L.S., Prof. of Zoology, Owens College.
Melvill, J. Cosmo, M.A., F.L.S.
Moore, Samuel.
Morgan, J. E., M.D.
Nix, E. W., M.A.
Sidebotham, Joseph, F.R.A.S., F.L.S.
Smith, Robert Angus, Ph.D., LL.D., F.R.S., F.C.S.
Williamson, Wm. Crawford, F.R.S., Prof. Nat. Hist., Owens College.
Wright, William Cort.

Associates.

Adams, Lionel.
Cunliffe, Peter.
Hartog, Marcus M., B.Sc., F.L.S.
Labrey, B. B.
Percival, James.
Plant, John, F.G.S.
Quinn, Edward Paul.
Rogers, Thomas.
Stirrup, Mark, F.G.S.
Sington, Theodore.
Tatham, John F. W., M.D.
Ward, Edward.
Young, Sydney.

Annual General Meeting, April 18th, 1882.

J. P. Joule, D.C.L,, LL.D., F.R.S., in the Chair.

Report of the Council, April, 1882.

The Treasurer's Annual Account shows that the balance against the General Fund has increased from £90 0s. 7d. on the 1st of April, 1881, to £120 12s. 5d. on the 1st of April, 1882; that the balance in favour of the Natural History Fund has diminished from £76 5s. 8d. to £35 7s. 11d.; and deducting the difference between these two sums from the Compounders' Fund, £125, there is a balance of £39 15s. 6d. in favour of the Society on the 1st of April, 1882, against a balance of £111 5s. 1d. on the 1st of April, 1881.

The number of ordinary members on the roll of the Society on the 1st of April, 1881, was 146, and 7 new members have been elected; the losses have been—resignations 9, and deaths 3. The number on the roll on the 1st instant was therefore 141. The deceased members are Mr. John Blackwall, Mr. A. G. Latham, and Mr. E. W. Binney.

Mr. John Blackwall, F.L.S., who died May 11, 1881, was born in Manchester in 1789, and the greater portion of his 92 years were devoted to the study of science. During his residence at Crumpsall Old Hall he made many interesting observations in natural history. The papers read before this and other societies were collected into a volume entitled "Researches in Zoology," which, originally published in 1834, came to a second edition in 1873. His Memoirs, chronicled in the Royal Society's Catalogue of Scientific Papers, are 82 in number, and were printed between 1821 and 1871. The most important of his works is the "Monograph on British Spiders," published for the Ray Society in 1861. This subject was one to which he had devoted especial attention after his removal from Manchester to Wales. Mr. Blackwall was for 60 years a member of this society, and he was also one of the oldest members of the Linnæan Society and of the British Association.

Mr. Arthur G. Latham was born December 29th, 1821, at Everton, near Liverpool; he joined the firm of Arbuthnot, Ewart, and Co., and spent a great part of his early life in India. Returning to England, he took up his residence in Manchester, about twenty-five years ago, since which time he resided at Weaste Hall, Pendleton. He was instrumental in founding the Microscopical and Natural History Section of the Literary and Philosophical Society in conjunction with his partner, the late Mr. Murray Gladstone, and took at all times a lively interest in all that appertained to the Society. He was most attached to the study of Coleoptera, both British and foreign, and amassed a very fine collection. Also of British Lepidoptera and birds' eggs and shells, both British and foreign. All these were sold at Steven's auction rooms in the year 1878; and latterly he directed his undivided attention to microscopic researches and the study of lichens and fungi. He died, somewhat suddenly, on April 23rd, 1881.

Edward William Binney, F.R.S., F.G.S., &c., our late President, was born at Morton, in Nottinghamshire, in 1812, and seems to have lost his father's care early, but a brother came to his help and enabled him to serve his apprenticeship to a solicitor in Chesterfield. Afterwards he completed his study in London, and came to Manchester in 1836. He was early led to the science in which he took the deepest interest, and to the peculiar department of it which he never left. His capacity for long walks gave him a great advantage. He was tall and powerful, and he had no wish to seek society. Indeed, he always spoke in a disparaging manner of the usual social intercourse in the middle and upper ranks, and delighted in rambling over the county and mixing with the men he chanced to meet, studying their ways and learning their observations. It was in this way he came to take much interest in the scientifically inclined working man, and he had a particular pride in speaking more highly of him than of the more learned or elaborately trained. Indeed, it was his opinion that to be a straightforward man and to observe well, seeing clearly what lay before one, was the most pleasant object in life.

That he himself was fitted for clear and accurate, as well as long-continued and patient observation, soon became manifest, and we have a list of papers written by him and extending over forty-two years.

He lived at Cheetham Hill (Manchester), attracted by its sandy soil, but spent his days at his business, or in reading at the Athenæum, or in attending to the affairs of this Society, in which he took a deeper interest than any member, if we are to judge by the trouble he took in directing its minutest details, so that for many years little was done without his will. His attention to business was so great that for thirty years he had not been absent from it for a fortnight at a time.

He attended well the meetings of the British Association for many years, and at the Geological and Palæontological Societies was well known as a contributor, while his studies of the flora and wood of the coal measures have helped greatly to make an important era in our knowledge. The writer must leave a geologist to sum up his labour and define his position as a scientific man. Of the 134 papers mentioned there are certainly only slight notices, but some, on the other hand, show laborious work, and have been left unfinished.

He joined Mr. Young in beginning works for the manufacture of paraffin oil, adding his savings to the small amount that was available at the time, after Mr. Young (now Dr. Young, of Kelly) had found it necessary to have aid in order to enlarge his establishment and begin his Scottish Works, the supply of oil in Derbyshire having failed. The firm was in this town called by the name of E. W. Binney and Co. The partnership continued during the existence of the patent, and Mr. Binney retired with a handsome sum, which he greatly increased by his investments. He spent a large portion of his later years at Douglas, in the Isle of Man, where his house, Ravenscliff, gave him a fine view of the Bay and of the sea, and was still to a great degree sheltered.

Mr. Binney was a remarkable man. He knew many people, but visited few, but to these few he was very strongly attached, whilst his tenacity of purpose prevented him from having sympathies with many, and caused him to put many people in an attitude of opposition, without making them enemies. In science he read very widely, but never wrote on anything outside the first field of his geological interest.

He had a peculiar horror, even loathing, for men who made a display, and, although a rich man, he lived in great simplicity. He admired great men, it is true, but his chief love was for the poor man who gained knowledge, although finding it difficult to gain bread. Thus he took up the case of Samuel Bamford, the author of 'The Life of a Radical,' and did not cease till he induced the Government to grant him a sum from the Civil List. A similar kindly feeling prompted him to great attention to Buxton the botanist, the author of 'The Botanical Guide to Manchester,' a remarkable man, who was known to Mr. Binney only when age had overtaken him. For many years he sat for hours daily in the office reading. Mr. Buxton, a shoemaker but a poor man, had never made above ten shillings a week all his life, and he lived, of course, in a poor street. It was remarkable, however, how fine his taste was, and how well informed he was found on all subjects, an educated gentleman, timid and shy as a child. Mr. Binney helped him to have his book published, and to obtain for it a fair sale. The delicacy of his treatment of this man was remarkable when men of great importance in the eye of society were sent away with a growl.

His pleasure in promoting and attending meetings of the scientific working men was great.

The small annuity obtained for Mr. Sturgeon was owing to the persistency of Mr. Binney.

Still, a purely benevolent life was not that of Mr. Binney; he was a man of business and a geologist. Geology had at an early period put out of his mind much of his knowledge of science, and his attention to the many affairs on hand very much in later years interfered with his geology. He has left a fine collection of geological specimens, and a fortune to his wife and three sons as well as three daughters.

It was his strong desire to have the rooms of the Society retained, but enlarged; and he intended to assist in raising a fund of five thousand pounds for this purpose, and also for obtaining the services of a librarian and editor. The Society has certainly suffered by his loss in this respect, but it has not the less suffered by the absence of his face and the full sympathy and clear sense which he introduced into so much of the work of the Society, although we often thought that, liberal as he was in politics, time had made him too conservative of some of the forms of the Society. We learn slowly to see the evils of rapid innovations.

Professor W. C. Williamson mentions as the first appearance of Mr. Binney as a geologist, a paper read by him in 1835 in conjunction with John Leigh, F.R.C.S., now Medical Officer of Health for Manchester. This paper was 'On Fossils found in the Red Marl at Newtown, in the valley of the Irk.'

The earliest paper recorded seems to be in the Trans. of the Geol. Soc., Vol. I., p. 35, entitled a 'Sketch of the Geology of Manchester and its Vicinity.' It was the work of three years, and showed in a remarkable degree the energy of the author's character. It was followed rapidly by others on the coalfields of Lancashire and Cheshire, on the marine shells of the Lancashire coalfields, and on the fossil fishes.

The enquiries which were of most interest to him were the constitution of coal and the conditions under which it grew. Next to these subjects came the action of glaciers and icebergs in distributing clay and boulders over the two counties especially in which he took interest.

A longer memoir will probably be read. At present we may indicate his chief discoveries by the following extract:

"*Carboniferous Flora. Part IV.*, 1875, pp. 98 and 99. *General Observations on Sigillaria, Anabathra, Diploxylon, and Stigmaria.*

"Ever since the time when the fossil plants of the coal measures first attracted attention, Sigillaria has occupied a chief place in the minds of botanists, for it is to be met with in the strata near most seams of coal, in a more or less perfect state of preservation. The trunks of this genus are of two kinds, namely, those distinctly ribbed and furrowed with leaf-scars on the ribs at greater or less distances, and those with the leaf-scars contiguous, and covering the whole surface of the trunk, both having them in a spiral arrangement around the axis. Nearly one hundred species have been described by different authors, who have made numerous species out of the same trunk; various parts of it being in a bad or good state of preservation. No doubt, when we are better acquainted with the true nature of the plant, the number of species will be greatly reduced.

"For a long time Sigillaria and Stigmaria were regarded as distinct genera of plants, and even now, on the Continent, some distinguished palæontologists are disposed to remain of that opinion. In the specimens first described by me, in the 'Philosophical Magazine' for 1844,* which were found in Mr. Littler's quarry, near St. Helens, Stigmaria was clearly traced to the trunks of the large, irregularly ribbed and furrowed Sigillaria, showing little, if any, traces of leaf-scars; but it was there distinctly stated that around these trunks smaller trunks were found standing, which showed all the characters of Sigillaria reniformis, with Stigmaria rootlets in the adjoining strata, pointing in the direction of the root, but not absolutely proved to be connected with it. On viewing the specimens as they originally stood in the quarry before their removal, little doubt could be entertained as to all the trees there found having had Stigmariæ for their roots. In some specimens, however, afterwards described by me in the 'Philosophical Magazine' for 1847, ser. 3, vol. xxxi. p. 259, the connection of Stigmaria as a root, with Sigillaria reniformis, S. alternans, and S. organum was clearly proved."

We cannot at present enter more into an account of Mr. Binney, but a more extended one is expected to appear. He spent much time at his house in the Isle of Man, and he seems to have hurried from it, fearing illness. His death took place on the 19th December, 1881.

Dr. Joule has presented the Society with an admirable portrait of Mr. Binney, painted by Mr. W. H. Johnson. It hangs on the walls of the meeting room—a characteristic remembrance of a man who has been a friend, pleasant, sympathetic, and wise, during an intimacy which, to a few

* 'Phil. Mag.', ser. 3, vol. xxiv. p. 168; and 1845, vol. xxvii. p. 241, &c.

of us, has lasted about forty years. His family have reason to thank him, and scientific history will not soon forget his labours amongst vegetation of the past, illustrating calm days in which coal grew to enrich us, or among the boulders and till, explaining the method in which they were deposited, making for us a pleasant and interesting land to dwell in.

The following papers and communications have been read at the Ordinary and Sectional Meetings of the Society, during the Session :—

October 4th, 1881.—"On Drops Floating on the Surface of Water," by Professor Osborne Reynolds, F.R.S.

"On the Mean Intensity of Light that has passed through Absorbing Media," by James Bottomley, D.Sc., F.C.S.

"Correction of the Formula used in Photometry by Absorption when the Medium is not perfectly transparent," by James Bottomley, D.Sc., F.C.S.

"Note on the Colour Relations of Nickel, Cobalt, and Copper," by James Bottomley, D.Sc., F.C.S.

October 18th, 1881.—"On the Failure of certain Mathematical Solutions of the Problem of the Motion of a Solid through a Perfect Fluid," by R. F. Gwyther, M.A.

"The Sea Gull in Salford," by William E. A. Axon, M.R.S.L.

"On the Numerical Extent of Personal Vocabularies," by William E. A. Axon, M.R.S.L.

November 1st, 1881.—"On the Manufacture of Salt in Cheshire," by Thomas Ward, Esq.

November 7th, 1881.—"On a Series of Preparations of Desmidiæ," by Mr. Wills.

November 8th, 1881.—"Note on a Passage of Pollux relating to the Formation of Purple Dye," by James Bottomley, D.Sc., F.C.S.

November 15th, 1881.—On the Pronunciation of Deaf-Mutes who have been taught to Articulate," by William E. A. Axon, M.R.S.L.

"On Professor C. A. Bjerkness's Experiments to Demonstrate the Analogies between Electrical and Magnetical Phenomena and some Hydrodynamical Phenomena," by William H. Johnson, B.Sc.

November 29th, 1881.—"On the Aniline Colours used in Water Colour Drawings," by Joseph Sidebotham, F.R.A.S., &c.

"On Cyclic Motions in a Fluid, and the Motion of a Vortex Ring of varying Curvature," by R. F. Gwyther, M.A.

December 5th, 1881.—"On the larval form of star-fishes, echinoïds, holotharids, and crinoïds," by Professor A. Milnes Marshall.

"On Limnotruchus Kirkii (Edgar Smith) from Lake Tanganyika, and on a new land Mollusc, Cyclosurus Marieri (Morelet), recently discovered by Prof. Morelet at the Mayotta Islands, about 300 miles N.W. of Madagascar," by J. Cosmo Melvill, M.A., F.L.S.

December 13th, 1881.—"Remarks on the Terms used to denote Colour, and on the Colours of Faded Leaves," by Edward Schunck, Ph.D., F.R.S.

January 10th, 1882.—"On Differential Resolvents, and Partial Differential Resolvents," by Robert Rawson, Esq., Assoc. I.N.A., Hon. Member of the Society.

January 24th, 1882.—"On the British species of *Erythrœa*," by Charles Bailey, F.L.S.

"On a dwarf form of *Campanula glomerata*, L., from the Isle of Wight," by Charles Bailey, F.L.S.

"On the Isle of Wight Station for *Lychnothamnus alopecuroides*, Braun," by Charles Bailey, F.L.S.

February 7th, 1882.—"The Colour Sense and Colour Names," by William E. A. Axon, M.R.S.L.

"Notes on Lead Pipes and Lead Contamination," by William Thomson, F.R.S.E.

February 13th, 1882.—"List of the Phanerogams of Key West, South Florida, mostly observed there in March, 1872," by J. Cosmo Melvill, M.A., F.L.S.

"Notes on Frog Tadpoles, Part I.," by Thomas Alcock, M.D.

February 14th, 1882.—"Notes on the Variable Stars U Canis minoris, V Geminorum, and U Bootis," by Joseph Baxendell, F.R.A.S.

March 7th, 1882.—"A Comparison between the Height of the Rivers Elbe and Seine and the State of the Sun's Surface as regards Spots," by Professor Balfour Stewart, LL.D., F.R.S.

"On Electro-Motor Machines for the transmission of mechanical power by means of Electricity," by Henry Wilde, Esq.

March 13th, 1882.—"On Cypræa Guttala (Gray)," by J. Cosmo Melvill, M.A., F.L.S.

"Lepidoptera of the Shetland Islands," by Hastings C. Dent, Esq.

"Notes on the Giant Dragon's-blood tree at Orotava, Teneriffe," by John Plant, F.G.S.

March 14th, 1882.—"Notes of some experiments made in February, 1881, on the Influence of Stress on the Electrical Resistance of Iron and Steel Wire," by William H. Johnson, B.Sc.

"On the Projection of a Solid on Three Co-ordinate Planes," by James Bottomley, D.Sc., B.A.

March 21st, 1882.—"Note on Envelopes and Singular Solutions, continued from Vol. XVII. Proc., p. 15," by Sir James Cockle, F.R.S., F.R.A.S., Corresponding Member of the Society.

April 4th, 1882.—"On the Occurrence of Oxide of Manganese (Wad) in the Yoredale Rocks of East Cheshire," by Arthur Smith Woodward, Student of Owens College. Communicated by Dr. Charles A. Burghardt.

Several of these papers have been passed by the Council for printing in the Society's Memoirs, and will appear in volume 8. The last paper to complete Volume 7 is now in the printer's hands, and the Volume will be ready for binding before the end of the present month.

The Council, at a meeting held on the 15th of November last, resolved "that the Memoirs of the Society be sent free to each Member, beginning with Volume 8."

In consequence of the ill-health and lamented death of the President, no action has been taken by the Council in reference to his proposed celebration of the Centenary of the Society.

At a meeting of the Council, held on the 19th of April last, it was resolved, on the motion of Mr. R. D. Darbishire, seconded by Dr. Joule, "that the Associates of each Section be empowered to vote in the election of Officers of the Section with the Members, and that Associates may be eligible for the Offices of the Section."

The Council again consider it desirable to continue the system of electing Sectional Associates, and a resolution on the subject will, as usual, be submitted to the Annual Meeting for the approval of the members.

Dr.

CHARLES BAILEY, TREASURER, IN ACCOUNT WITH THE SOCIETY,
STATEMENT OF THE ACCOUNTS

	£	s.	d.	1881-2 £	s.	d.	1880-1 £	s.	d.
1881.—April 1.									
To Cash in hand				111	5	1	124	10	3
1882.—March 31.									
To Members' Contributions :—									
Arrears 1880-1, 1 Admission Fee	2	2	0						
,, ,, 11½ Subscriptions	24	3	0						
Old Members' Subscriptions, 1881-2, 121 at £2 2s.	254	2	0						
New Members' ,, ,, 6 ,,	12	12	0						
,, Admission Fees, 1881-2, 6 ,,	12	12	0						
				305	11	0	302	8	0
To one Associate's Subscription for Library, 1881-2	0	10	0						
To Sectional Contributions :									
Physical and Mathematical Section, 1881-2	2	2	0						
Microscopical and Natural History Section, 1881-2	2	2	0						
				4	14	0	6	16	0
To use of Society's Rooms :—									
Manchester Geological Society, to 31st March, 1881				30	0	0	33	0	0
To Sale of Society's Publications				8	10	6	10	19	7
To Natural History Fund :									
Dividends on £1225 Gt. Western Stock (11 months, 1881-2)				54	18	8	59	15	3
To Bank Interest, less Bank Postage, to 31st December, 1881				2	14	4	1	18	4
				£517	13	7	£539	7	5

1882.—April 1. To Cash in Manchester and Salford Bank £39 14 8

11th April, 1882.

Audited and found correct,

R. E. CUNLIFFE.
J. A. BENNION.

PHILOSOPHICAL SOCIETY.

FROM 1ST APRIL, 1881, TO THE 31ST MARCH, 1882, WITH A COMPARATIVE FOR THE SESSION 1880-1881.

Cr.

1882—March 31.	1881-2. £ s. d.	1881-2. £ s. d.	1880-1. £ s. d.	1880-1. £ s. d.
By Charges on Property :—				
Chief Rent	12 12 8		12 12 0	
Insurance against Fire	12 17 6		12 17 6	
Property Tax	3 10 10		4 5 0	
Repairs, Whitewashing, &c.	3 6 5		2 16 10	
		32 7 5		32 11 4
By House Expenditure :—				
Coals, Gas, Candles, and Water	17 11 4		17 19 7	
Tea and Coffee at Meetings	17 1 10		16 6 1	
House Duty	6 7 6		6 7 6	
Cleaning, Brushes, Sundries	5 6 8		5 11 2	
		46 7 4		46 4 4
By Administrative Charges :—				
Wages of Keeper of Rooms	57 4 0		57 4 0	
Postages and Carriage of Parcels	18 12 0		24 5 6	
Attendance on Sections and Societies	9 9 0		9 9 0	
Stationery and Printing Circulars	14 2 1		11 16 6	
Distributing Memoirs	3 0 0		— —	
		102 7 1		102 15 0
By Publishing :—				
Printing Memoirs	51 9 0		42 16 0	
Printing Proceedings	54 1 0		41 4 0	
Wood Engraving and Lithographing	1 11 6		8 5 0	
Editor of Memoirs and Proceedings	50 0 0		50 0 0	
		157 1 6		142 5 0
By Library :—				
Binding Transactions	0 0 0		8 17 4	
Binding Books for Library	0 0 0		16 16 11	
Books and Periodicals	22 4 8		16 0 5	
Assistant in Library	19 12 6		20 10 0	
Palæontographical Society for 1882	1 1 0		1 1 0	
Ray Society for 1882	1 1 0		1 1 0	
		43 19 2		64 6 8
By Natural History Fund :—				
Grant to Section for Books	80 0 0			
Natural History Works	15 16 5			
		95 16 5		40 0 0
By Balance		39 14 8		111 5 1
		£517 13 7		£539 7 5

	1881-2. £ s. d.	1881-2. £ s. d.
Compounders' Fund :—		
Balance in favour of this Account, April 1st, 1882		125 0 0
Natural History Fund :—		
Balance in favour of this Account, April 1st, 1881	76 5 8	
Dividends as above	54 18 8	
	131 4 4	
Less paid for Natural History Works	95 16 5	
Balance in favour of this Account, April 1st, 1882		35 7 11
		160 7 11
General Fund :—		
Balance against this Account, April 1st, 1881	90 0 7	
Expenditure, 1881-2, as above	382 2 6	
	472 3 1	
Receipts, 1881-2, as above	351 9 10	
Balance against this Account, April 1st, 1882		120 13 3
Balance in favour of the Society, April 1st, 1882		£39 14 8

MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

CHARLES BAILEY, TREASURER, IN ACCOUNT WITH THE SOCIETY, FROM 1ST APRIL, 1881, TO THE 31ST MARCH, 1882, WITH A COMPARATIVE STATEMENT OF THE ACCOUNTS FOR THE SESSION 1880-1881.

Dr.

	£ s. d.	1881-2 £ s. d.	1880-1 £ s. d.
1881.—April 1.			
To Cash in hand		111 5 1	124 10 3
1882.—March 31.			
To Members' Contributions:—			
Arrears 1880-1, 1 Admission Fee	2 2 0		
" " 11½ Subscriptions	24 3 0		
Old Members' Subscriptions, 1881-2, 121 at £2 2s.	254 2 0		
New Members' " " 6 "	12 12 0		
" Admission Fees, 1881-2, 6 "	12 12 0		
		305 11 0	302 8 0
To one Associate's Subscription for Library, 1881-2	0 10 0		
To Sectional Contributions:			
Physical and Mathematical Section, 1881-2	2 2 0		
Microscopical and Natural History Section, 1881-2	2 2 0		
		4 14 0	6 16 0
To use of Society's Rooms:— Manchester Geological Society, to 31st March, 1881		30 0 0	33 0 0
To Sale of Society's Publications		8 10 6	10 19 7
To Natural History Fund: Dividends on £1225 Gt. Western Stock (11 months, 1881-2)		54 18 8	59 15 3
To Bank Interest, less Bank Postage, to 31st December, 1881		2 14 4	1 18 4
		£517 13 7	£539 7 5

1882.—April 1. To Cash in Manchester and Salford Bank ... £39 14 8

11th April, 1882.

Audited and found correct,
R. E. CUNLIFFE.
J. A. BENNION.

Cr.

1882—March 31.	1881-2. £ s. d.	1881-2. £ s. d.	1880-1. £ s. d.	1880-1. £ s. d.
By Charges on Property:—				
Chief Rent	12 12 8		12 12 0	
Insurance against Fire	12 17 6		12 17 6	
Property Tax	3 10 10		4 5 0	
Repairs, Whitewashing, &c.	3 6 5		2 16 10	
		32 7 5		32 11 4
By House Expenditure:—				
Coals, Gas, Candles, and Water	17 11 4		17 19 7	
Tea and Coffee at Meetings	17 1 10		16 6 1	
House Duty	6 7 6		6 7 6	
Cleaning, Brushes, Sundries	5 6 8		5 11 2	
		46 7 4		46 4 4
By Administrative Charges:—				
Wages of Keeper of Rooms	57 4 0		57 4 0	
Postages and Carriage of Parcels	18 12 0		24 5 6	
Attendance on Sections and Societies	9 9 0		9 9 0	
Stationery and Printing Circulars	14 2 1		11 16 6	
Distributing Memoirs	3 0 0		— —	
		102 7 1		102 15 0
By Publishing:—				
Printing Memoirs	51 9 0		42 16 0	
Printing Proceedings	54 1 0		41 4 0	
Wood Engraving and Lithographing	1 11 6		8 5 0	
Editor of Memoirs and Proceedings	50 0 0		50 0 0	
		157 1 6		142 5 0
By Library:—				
Binding Transactions	0 0 0		8 17 4	
Binding Books for Library	0 0 0		16 16 11	
Books and Periodicals	22 4 8		16 0 5	
Assistant in Library	19 12 6		20 10 0	
Palæontographical Society for 1882	1 1 0		1 1 0	
Ray Society for 1882	1 1 0		1 1 0	
		43 19 2		64 6 8
By Natural History Fund:—				
Grant to Section for Books	80 0 0			
Natural History Works	15 16 5			
		95 16 5		40 0 0
By Balance		39 14 8		111 5 1
		£517 13 7		£539 7 5

	1881-2. £ s. d.	1881-2. £ s. d.
Compounders' Fund:—		
Balance in favour of this Account, April 1st, 1882		125 0 0
Natural History Fund:—		
Balance in favour of this Account, April 1st, 1881	76 5 8	
Dividends as above	54 18 8	
	131 4 4	
Less paid for Natural History Works	95 16 5	
Balance in favour of this Account, April 1st, 1882		35 7 11
		160 7 11
General Fund:—		
Balance against this Account, April 1st, 1881	90 0 7	
Expenditure, 1881-2, as above	382 2 6	
	472 3 1	
Receipts, 1881-2, as above	351 9 10	
Balance against this Account, April 1st, 1882		120 13 3
Balance in favour of the Society, April 1st, 1882		£39 14 8

On the motion of Mr. A. BROTHERS, seconded by Mr. J. A. BENNION, the Report was unanimously adopted and ordered to be printed in the Society's Proceedings.

On the motion of Mr. WILLIAM E. A. AXON, seconded by Mr. JAMES SMITH, it was resolved unanimously: That the system of electing Sectional Associates be continued during the ensuing Session.

The following gentlemen were elected Officers of the Society and Members of the Council for the ensuing year:—

President.

HENRY ENFIELD ROSCOE, B.A., PH.D., LL.D., F.R.S., F.C.S.

Vice-Presidents.

JAMES PRESCOTT JOULE, D.C.L., LL.D., F.R.S., F.C.S.
EDWARD SCHUNCK, PH.D., F.R.S., F.C.S.
ROBERT ANGUS SMITH, PH.D., LL.D., F.R.S., F.C.S.
REV. WILLIAM GASKELL, M.A.

Secretaries.

JOSEPH BAXENDELL, F.R.A.S.
OSBORNE REYNOLDS, M.A., F.R.S.

Treasurer.

CHARLES BAILEY, F.L.S.

Librarian.

FRANCIS NICHOLSON, F.Z.S.

Other Members of the Council.

ROBERT DUKINFIELD DARBISHIRE, B.A., F.G.S.
BALFOUR STEWART, LL.D., F.R.S.
CARL SCHORLEMMER, F.R.S.
JAMES BOTTOMLEY, B.A., D.SC., F.C.S.
WILLIAM HENRY JOHNSON, B.SC.
HENRY WILDE.

On the motion of Mr. R. D. DARBISHIRE, seconded by Mr. CHARLES BAILEY, it was passed unanimously: That this Annual Meeting of the Society cannot separate without acknowledging in a special manner its sense of its own peculiar loss on the death of its late president Mr. Binney. Without dwelling upon the honour conferred on it by his own distinction as a man of science, or the support given to all the business of the Society by his most assiduous attention to its work and welfare, the members desire to place on record the affectionate regard with which they cherish the memory of Mr. Binney's constant and genial participation in their proceedings, of his never-failing encouragement of genuine research, and of his dignified impersonation amongst them of faithful and successful self-culture.

"Preliminary Remarks on Observations made in Davos in the Winter 1881-82," by ARTHUR WM. WATERS, F.G.S., F.L.S.

The principle of arresting disease by a residence in high climates is now recognised by leading medical men, and has been tried in various parts of the world, and it is very much to be hoped for the sake of Davos that the experiment will soon be tried in other parts of Europe, and in this immediate neighbourhood the names of Arosa and Clavadel, besides places in the Engadine, have been mentioned as well situated. Everything connected with Davos is of scientific importance, as new places should study the experience gained here.*

* Davos is a long valley with five villages—Dörfli, Platz, Frauenkirch, Glaris, and Monstein. In Platz, 1,560 metres above sea level, the experiment was first made of wintering for the cure of consumption, and since then there have been patients in Dörfli and a few in Frauenkirch, but far the largest number have lived in Platz, and, therefore, when I speak of Davos, it must frequently be understood to refer to the invalid quarters of the valley.

On arriving in Davos, after an absence of 11 years, I naturally found it much changed, and among the first things I saw was a bank and gas-works, and then I felt the simplicity of the Davos I had known was passed away, and afterwards found that with that simplicity some of the advantages of the place had also disappeared, for in the 17 years since the place was first tried it has lived a very spendthrift youth, and instead of a simple mountain village with two moderate sized hotels, as I first knew it, it is now an indifferently built small town with many of the hotels in most unsatisfactory positions, and none have chosen as good a one as the first hotel which was built for Swiss visitors, and almost a climax has been reached by building a German hospital in one of the most unfavourable places.

When I came here for the first time the number of visitors was much larger in the summer than in the winter, whereas it is now principally a winter resort. But this was to be expected, for those who took an interest in it at first saw that it had advantages in winter not possessed by other places, whereas the summer climate is similar to a large number of Alpine stations; but this change from a summer to a winter resort is a disadvantage to those who come for the winter, for now all the hotels are full in this season, whereas 11 years ago, when there were only two, these were filled in the summer; but in the winter, when the patients are more indoors there was more space and a purer air was breathed than is now the case, as the hotels were then only half or a third full.

In the winter, 1870-71, there were 55 invalids with a few friends accompanying them, whereas this winter the number of visitors has been about 1,000, which means an addition of considerably more than two thousand living in the valley since I first knew it, and it is therefore now necessary to see what the effect of this change is likely to be; but before going into that I may say that the Swiss issued a commission to see where consumption was most abundant, and to examine the statement as to there being an immunity from consumption at a certain height as stated by Dr. Lombard and others. The report was edited by Dr. E. Müller.*

Nearly all the doctors applied to sent in their reports, some few regularly during the five years which the commission sat, but although the report from Davos would have been the most interesting in Switzerland, there is only one line and that refers only to two years. However, from the parallel valley of the Engadine some important reports were sent, and since then Dr. Ludwig has published additional particulars relating to the Engadine.†

The results arrived at by the commission were that there is no such thing as an immunity boundary, but that consumption becomes less common as we ascend, but instead of being found most rare in the highest villages those between 1,300—1,500 metres (4,265—4,921 feet) have fewer cases than those between 1,500—1,800 metres (4,921—5,905 feet).

Dr. Hermann Weber has already in his Klimotherapie‡ corrected the statement he made on the authority of others, and as I repeated it in the pamphlet|| I wrote on Davos I also take this earliest opportunity of correcting it, which is all the more necessary as this does not yet seem to have been done in what may be called the Davos literature. However, we see from Dr. Ludwig's figures that phthisis is very rare in the Engadine; and although we cannot any longer say that the inhabitants who have never quitted the valley of Davos have never been attacked by it, yet the cases or case are so few (I believe it is now some time since a case occurred) that we may say that, so far, there has been

* Die Verbreitung der Lungenschwindsucht in der Schweiz, von E. Müller. Winterthur, 1876.

† Das Oberengadin, von Dr. J. M. Ludwig. Stuttgart, 1877.

‡ Ziemssen's Allgemeine Therapie, vol. II., pt. 1.

|| Klimatologische Notizen ü. den Winter im Hochgebirge, von Arthur Wm. Waters. Basel, 1871.

almost immunity from this scourge for those who have never left their native valley.

The commission, referred to, showed how much more free agricultural and thinly populated districts were from consumption, while in the higher valleys where there was a large manufacturing population, as in the watch making districts of the Jura, then the death-rate became considerable; and my own opinion is, that Davos, with a manufacturing population, would have been absolutely unhealthy, but as this can only be a matter of personal opinion, it is necessary to give the reasons that have led me to this conclusion.

The position of the valley is most wonderfully favourable for a health resort, being very wide, and well protected from the north and east, and being so splendidly enclosed, there is remarkably little wind in winter, but this very stillness of the air which has made Davos unrivalled is a cause of danger as soon as there are a large number of houses to pour their smoke into the air, and their drainage on to the land or into the river. We have now a very serious smoke and drainage nuisance, and if changes are not soon made the history of Davos will resemble that of many southern health resorts, where favourable results have at first been obtained, leading to exaggerated reports, upon which has followed a rush of suitable and unsuitable cases; then large hotels have been built, but sanitary arrangements have lagged behind, while instead of providing for a quiet simple life, which is so frequently necessary for consumptive patients, the hotel keepers devoted their attention to furnishing unsuitable amusements; and theatres and other large buildings into which patients have congregated, have helped to ruin many resorts. These are partly the reasons that the favourite places of 20 years ago have been replaced by newer ones. An overgrowth is more to be feared in an enclosed valley, where there is only a very limited space, than would be the case on the sea coast.

The question of drainage has received some attention from the visitors the last two winters; and this winter in two little pamphlets attention was drawn to it, and also Dr. Holland wrote to the local papers a letter which did not receive the attention it deserved. Shortly after, this paper intimated that the English were inclined to think too much of drainage, because the Prince of Wales had typhoid a few years ago, but the editor was probably unaware, or else ignored the fact, that at the time he wrote this a petition had just been got up entirely by Germans and Dutch, and was signed by over two hundred visitors, with very few exceptions belonging to those nationalities. This was sent to the central authorities of the canton in Chur, about the same time as a petition, to the same effect, from one English hotel with 70 signatures, and if it had been thought advisable to make the petitions more general there would have been no difficulty in obtaining about 400 more names. The answer is, that certain laws relating to drainage, and which will diminish the evils complained of, were passed May, 1881, by the Landgemeinde. Although this law ought to have been passed at least ten years ago, hardly anything has yet been done towards carrying it out; but probably the action of the visitors will lead to this being done in the course of the next few months.

Not very long after these petitions a letter from Mr. J. Addington Symonds appeared in the *Pall Mall Gazette*, calling attention to an overgrowth of Davos, and pointing out some present evils. This caused very much irritation among some of the influential inhabitants, and at first they were inclined to treat it all as incorrect; but finding that the general opinion among the visitors was that Mr. Symonds was correct in the main points, their tone was very much changed. Perhaps if this letter had remained in Mr. Symonds' desk for a week the irritation might have been lessened by the modification of one or two expressions, but

I think that he was too good a friend to Davos to have dealt with the facts less strongly, and in a second letter he pointed out, that what he had written was entirely done for the advantage of Davos, towards which he had the most kindly feelings. Mr. Symonds' communication was followed by Dr. Gwillim (who had been residing here for some months) in a letter to the *Lancet*, in which he supported Mr. Symonds, saying that the drainage was in a disgraceful condition, and probably that the results obtained in Davos being now less satisfactory than they were at the commencement must be attributed to the causes pointed out by Mr. Symonds.

After numerous threats as to the answers which were coming, the results were: a scurrilous one from a partially-educated man who did not deal with the facts, but confined himself to charging Mr. Symonds with writing merely to forward personal and financial interests; and afterwards an answer signed by the Curverein, but which must be considered as an hotelkeeper's answer, and which contained misleading statements, especially those indicating that the number of people living in the large hotel had not been increased by changes made by the company owning it.

These agitations have shown that something must be done for Davos to retain the high character that it has won, and the hotelkeepers in consequence met together and decided to remove some of the evils, especially those caused by the least powerful members of the community.

If public opinion makes itself felt in other years, and if the attempt made by those who have built the theatre and other public rooms towards what they call Concentration des Kurlebens is unhesitatingly resisted, then Davos may be saved; but if the warnings given by those who believe most in the principle of the climate and are its best friends, are neglected, then it will soon be ruined, and the judgment of the future may be that the whole thing has been a gigantic fraud, and other places will suffer in consequence.

As I was the first genuine Englishman to try this climate for the winter—now twelve years ago, I feel it all the more my duty to record the impressions made upon me now, and as I have always been one of the most enthusiastic believers in such climates for suitable cases, and have on both occasions derived great benefit, I am anxious that warnings given may not be neglected, but that this wonderful health-giving treasure may be preserved to Europe for many years and not be endangered by any who, either through ignorance of curative principles or zeal to become rich, are led to overlook the true interests of the valley.

From these impressions I must pass on to the observations which I have made during the winter; but as I have not yet had time to put all my figures together, or revise them, I can only refer to general results, but perhaps by so doing I may receive some valuable hints for next winter's work from those who have more experience in such things than I possess.

Evaporation.

The amount of moisture in the air is one of the most difficult questions to deal with in such a climate as Davos, and much misunderstanding has existed concerning it. Dr. Spengler would lay greater stress on the amount of absolute moisture in the air than on the relative or percentage of moisture, and I said (*loc. cit.*) that it was not enough to consider the relative moisture, but that "in my opinion the comparison of the weight of moisture in the air was to be recommended, as in that way we could see what we were breathing," which is no doubt correct, though I should, if writing the same thing now, express myself somewhat differently, for the physiological action must depend more on the evaporation from the body and lungs than on any other factor, and this must be divided into two categories—firstly the action on the skin, and secondly on the lungs through the air we breathe.* I therefore considered that a series of observations on evaporation might be climatologically important from several standpoints.

The evaporation was made in a tin 27 cm. by 22 cm. by 5 cm. (nearly 9 in. by 11 in.), painted white, and hung up by a wire in a screen 90 cm. wide by 75 cm. by 60 cm. high, placed in the shade of a music pavilion. This pavilion (27 feet diameter) was nothing more than a roof supported by twelve pillars, thus allowing a free passage of air, but protecting the screen from the sun during the winter months of November, December, January, and February, with the exception of a few minutes during the last days of the month; also during the shortest days the sun shone for a short time between the pillars, but then the screen was protected by cane blinds.

On the first of December there was a thaw most of the day, and three times in the month a partial thaw. In January there was no thaw, and until the 23rd of February nothing more than the melting of a few drops in the warmest part of the day, but after that the ice was mostly thawed.

The observations of value are those when the ice was not melted, as when there was a thaw the evaporation would neither represent that of ice nor of water, as then the temperature of the water would remain at freezing point although the air might be many degrees higher, so that then little, or in extreme cases no evaporation might take place.

During the months of December, January, and February, the dew point was never above freezing; at nine o'clock the temperature of evaporation was also never above 32; at 11 a.m. it was twice slightly above; at 1 p.m. seven

* In climatological considerations the amount of moisture carried off from the lungs receives much more attention than that removed by the skin, but as the amount removed in health, as perspiration, is greater than that expired, both must be looked upon as of primary importance.

times; at 3 p.m. fourteen times. The temperature of the air rose more than half the days above freezing in the middle of the day, though only in a few exceptional cases above that point in the morning. This winter has, therefore, been an unfavourable one for my observations, as it is here quite an exception for the air to rise so often above freezing in the winter months. The tin of ice was weighed daily (at 11 a.m.) with a first rate beam 47 cm. long, made by Young & Son, of London, and guaranteed to weigh 5 Kilo., and it turned with a twentieth of a gramme.

*The evaporation from the ice in December was 12·24 mm.; January 15·27 mm.; February 15·018 mm.

The smallest amount which I have had to measure in the twenty-four hours was 0·084 mm., Dec. 13th, during which time the temperature varied from 26·6° F. to about 19° F., with hardly any wind; the largest amount with ice in the tin all the time was 0·88 mm. on Dec. 11th, the temperature rising to 35·7 at 11 a.m., but until about 8 a.m. the temperature must have been moderately below freezing; on the night of the 10th there was a considerable wind. Once (Nov. 28th), with the tin full of water, the evaporation was 2·314 mm., but then the temperature was high all the time, rising to 47° F., yet there was very little wind.

This winter has not been favourable for comparing the evaporation of snow with that of ice, but I think the results obtained seem to be, that when the tin is filled with snow the evaporation is for the first day or two about 10 per cent more than that of water, it then becomes more consolidated and evaporation in both is about equal.

On one occasion I buried a tinful of snow up to the rim

*I find that when there is water in the tin the temperature lags very much behind that of the air, there being sometimes as much as 5° to 8° F. difference between the air and water. This must always be a cause of difficulty in measuring evaporation, and therefore for comparison the depth of water should always be the same, and perhaps the quantity I used (viz. two inches) was too large.

in deep snow, exposed to the sun* from 9.15 a.m. to 3 p.m., the loss was 0·109 mm., or a trifle less than from the ice in the shade during the same time, where, however, the temperature was above freezing for about an hour. The loss from the ice in the 24 hours was 0·429 mm. This form of observation is probably worth constant repeating, and next winter I purpose continuing the observations, with some important modifications which experience has shown to be advisable.

Of course the evaporation must be small when the temperature is low (although somewhat accelerated here by the low barometrical pressure). The figures for Paris and Vienna are:—

	Paris, 1875.		Vienna, mean of many years.
December,	11 mm.	...	18 mm.
January,	34 mm.	...	13 mm.

In Paris, the yearly total is 776 mm.; in London, about 650 mm.

The popular belief here is, that the evaporation in Davos is extremely rapid under all circumstances, and this is no mere theoretical question, for the false belief that newly built houses dry miraculously rapidly has led to serious results, and, probably through this error, the grave has closed over some whose life might otherwise have been prolonged. The south side of a house into which the powerful winter sun pours is dried very rapidly, but the rest of the house dries but slowly; and when here eleven years ago, I examined several houses just built, and tried to combat the false ideas then held.

This winter a large café and theatre, into which very little winter sun enters, was opened immediately upon completion, and the results were that the larger proportion of patients in the hotel to which these buildings belong were in a few days suffering from colds, some sufficient to

* The solar radiation on the 9th as measured by a black bulb thermometer in vacuo was 104° F. The day was cloudless.

call in medical aid, but a much larger number were only slight cases.

The evaporation in my room in a square glass dish of the same size as the tin out of doors, and placed on book shelves sufficiently open for air to pass behind, gave from about 0·85 mm. to 1·11 mm. per day, not varying much from day to day, though, as a rule, greatest when the temperature out of doors was coldest. Average temperature of room 55° F. to 61° F. Dr. Volland's figures reduced to millimeters give a mean evaporation in the room from 1·14 mm. to 1·18 mm. per day for the months of December, January, and February.

Comparison of Instruments: Dry and Wet Bulb.

My screen was made solely for the evaporation experiments and was very open, being too open for regular meteorological observations, as thus there was a danger of snow being blown in laterally; on the other hand, for the comparison of instruments, this openness was an advantage; so when a Mason's (August's) wet and dry bulb hygrometer, made by Casella, was offered to be lent me by Mr. Steffen, as well as two hair hygrometers similar to those used by the Swiss meteorological stations, offered me by Dr. Ruedi and Mr. J. Addington Symonds,* I yielded to the temptation and hung them up in my box, at an 18 inches lower level than my ice tin, and by short-interval observations followed their action in various ways through the winter.

As is well known, the difficulties in obtaining the amount of moisture correctly with the wet and dry bulb thermometers, when the temperature is below freezing, are very great. There are difficulties which occur about the time that the freezing point is passed which probably cannot be got over, but I think that when the temperature is steadily below freezing for a long time, precautions may be taken which will lead to a greater amount of correctness

* Mr. Martini, the optician, also lent me instruments for temporary comparison.

than has yet been obtained. As long as the bulb can be supplied with water this is constantly flowing up the thread, where it soon attains the temperature of evaporation, and then a comparatively equal film of water is always maintained in the muslin surrounding the bulb, but as soon as the temperature is below freezing the personal equation plays a large part, for now we shall find that the covering of the bulb is a very material point, as well as the thickness of the ice sheet, which is no longer automatically arranged, and further, the temperature of the wet bulb after an ice sheet has been formed will vary very much from time to time. The instructions usually given are that the bulb should be wetted about half an hour before an observation, but I find that in practice many observers only do this a quarter of an hour before. I have already called attention to this not being long enough, and although I have not this winter obtained as striking results as I did some winters ago, yet through some hundred of observations, in which special attention was paid to the dew point, as that cannot change so rapidly or irregularly as the temperature, I am able to fully confirm what I then wrote as to a longer time being required. This is most important in relation to the Davos climate, because it has been charged against Davos that it is not dry, and while the relative moisture is no doubt greater than the popular talk about the place would lead us to expect, yet I think that many of the figures which have been published would make it appear moister than is really the case.

The first observations were made by Dr. Spengler from 1867 to 1871. These were made in a metal box attached to the side of the house, as is usually done in Switzerland, and as I felt somewhat doubtful as to the results obtained in a metal box so near a house, I put up, in 1870, a very large screen consisting of an inner box with single louvres, surrounded by an outer one at a distance of six inches, also with single louvres, but sloping in an opposite direction. The screen was placed about twenty feet from all buildings, but during the winter months was, with the exception of a short time in the day, in the shade. Rightly or wrongly, I considered this screen was preferable for this climate to a Stevenson's screen, and that yet observations so made were comparable with those made in England.

Although my times of observation were not quite the same as those of Dr. Spengler, yet they admit of certain comparisons being made, and we find that there apparently was very little difference in the early morning temperature, though my registers seem to have been a little the lowest; also in the middle of the day, the difference as a rule was not great, though then mine were rather the highest.* When we come to the moisture then the observations are more unsatisfactory, for while the mean would not differ very much, yet when detail examination is made we find very serious differences, sometimes in one direction, sometimes in another, and I have therefore in these cases compared with neighbouring places, and it is clear that sometimes the error was on my side, and sometimes on that of Dr. Spengler; and, as we may conclude in hygrometrical measurements that the lower figure is the correct one, this shows that Davos is much drier than the figures obtained by either of us would seem to indicate. On mentioning this to Dr. Spengler, he considered that his error would arise from the bulb having been wetted too short a time before the observation, which I have already shown to be a source of frequent error. The detail comparison entirely bears this out, whereas it now seems on similar examination that my error was in the opposite direction, and, therefore, although I took every pos-

* Our published monthly means are :—

	Spengler.		Waters.		Difference.
November, 1870......	—1·39°C.	...	—1·0° C.	...	0·39.
December, 1870......	—8·12°C.	...	—8·20°C.	...	0·08.
January, 1871......	—9·68°C.	...	—9·69°C.	...	0·01.
February, 1871......	—5·06°C.	...	—4·09°C.	...	0·97.

sible care by frequently seeing that the bulb was in order, and no doubt Dr. Spengler was equally conscientious in his observations, yet it does seem that we both obtained too high a percentage of moisture

The danger of error from these sources may to a large extent be overcome by having three thermometers, one of which will remain the dry bulb, whereas the other two should be kept wet, and one should have a recently formed sheet of ice, whereas the other should have an older one to which water has been added at least an hour before, for though in a few cases the temperature of evaporation was soon reached, yet as a rule this is not attained in an hour. I intend to use such a thermometer next winter, and consider that to obtain correct results this is almost a necessity, when the temperature is below freezing. As there is little wind here it would also be well to create a current by a revolving fan, as is done by the Italian meteorologists.

The observations taken by Mr. Steffen since 1876 give for the winter months a materially less percentage of moisture in the air than Dr. Spengler obtained, and no doubt from the causes just mentioned. Unfortunately the position of Mr. Steffen's house is very unfavourable for meteorological observations, as the instruments are sheltered by the house from the east and north winds, and a north-east wind very frequently blows, as valley wind, where his house is situated.

Hair Hygrometer.

Knowing the difficulty with the wet and dry bulb hygrometer, it becomes an important question to find out how far hair hygrometers are available in cold weather, especially as the Swiss meteorologists are now using them, and therefore I observed their action carefully to see if they would be useful for my next winter's work, and I soon saw from the daily curve which they gave, compared with Mason's, that they were not sufficiently sensitive, and did not alter rapidly enough; so to further test their action I several times removed one from my room to my box out of doors, and *vice versa,* and then compared, to see how soon the instrument removed corresponded with the one which had not been recently changed, and I found that it was several hours before the readings were similar, and further noticed that when brought from the cold air to the warm room the readings were much sooner reliable than when it was removed to the cold.

As an example similar to several others, hygrometer No. 1 had, on January 7th, been out of doors for some weeks, when I put No. 2 out from my room, at 10 a.m., when it stood at 32·5. No. 1 stood at 66 out of doors. The course of the two, neglecting small fractions, is shown in the following tables:—

Jan. 7th.	10 a.m.	11 a.m.	1 p.m.	3 p.m.	8th. 9 a.m.	11 a.m	1 p.m.	3 p.m.
No. 1.	66	61	50	52	73	62	51	42
No. 2.	—	47	56	59	72	61	51·5	42·5
Difference ...		− 14	+ 6	+ 7	− 1	− 1	+ 0·5	+ 0·5

Jan. 9th.	9 a.m.	11 am.	1 p.m.	3 p.m.	Jan. 10th, 9 a.m.
No. 1.	55	52	42	38	82
No. 2.	54	52	41·5	38	80
	− 1	0	− 0·5	0	− 2

From which we see that in the first hour it had only risen 15 per cent, that afterwards it became too high, and was not reliable all that day. It was, of course, a severe test for the instrument, but as we have had as great a difference as 40 per cent out of doors in one day, any instrument which changes so slowly is unsuitable for exact meteorological work.

Besides this slowness of action these two hygrometers, which I have reason to believe are first-rate instruments of their kind, will not always give similar indications. For instance, when

No. 1 showed 88, No. 2 at various times indicated	...	*92	88	95
Do.	78	80	84	
Do.	73	79	79	81
Do.	42	48	49	48

Besides these I had the loan for a short time of two other superior instruments, made by known makers, and in each case I found great irregularity of action. These four instruments cost from 35—45 francs each. A short pillar gut hygrometer was also lent me, but as these should never be considered as meteorological instruments (though they may be useful in a room), comparison of their action is here unnecessary.

In consequence of these comparisons I do not feel inclined to place absolute reliance upon the hair hygrometer, though I think it most useful to have one in every meteorological box, as it may help over some points of difficulty; for instance, you go to take your reading and find that the ice on the wet bulb has only partially thawed, and consequently you know that the reading is valueless, but by now noticing the hair hygrometer and returning in half an hour to complete the observation, fairly reliable results may be obtained.

Regnault's Hygrometer.

Towards the end of the winter I obtained from England a Regnault's hygrometer, but as the quicksilver of one of the thermometers became divided on the journey, through there being some air in the tube, I have not made as many control observations as I otherwise should have done, but the observations made will nevertheless enable me to form an idea as to which formula should be used, and further, as this is an instrument requiring considerable practice, I am glad to have had some experience with it, as I see that here much will depend on its being properly placed, because, as

* The last examples are given uncorrected, whereas I applied a correction to the series previously quoted, commencing Jan. 7th. Of course it will be understood that the correction must be the addition or subtraction of equal arcs and not of degrees of moisture.

the gold cup is sometimes reduced 20—30 degrees* before dew point is obtained, it is evidently necessary that it should be protected from the wind; but even then we may be sure that the outside of the cup will be slightly warmer than the inside. When this form of hygrometer has been more used, I think that we shall better understand the Davos climate.

Position of Instruments.

In order to obtain the relative moisture correctly, it is of course of the utmost importance that the instruments should be correctly placed and protected; and I have therefore given some attention to this question, which seems to be one of the most difficult meteorological problems, and is now receiving much attention from meteorologists. It will be seen that I have on both occasions placed my screen in the shade, and I think that I may now definitely say that such an arrangement is necessary, for here when the solar radiation is so intense and the movement of the air but slight, a Stevenson's screen, as now commonly used in England, is warmed by the sun,† so that the temperature is

* On April 7th, seeing the hair hygrometer showed the air to be very dry (under 17 per cent), I used the Regnault and found the dew point 4° F. with the air temperature 49·5° F., thus giving about 14½ per cent of moisture. On this occasion, therefore, the temperature of the cup was reduced 35 degrees.

† In the pamphlet to which I have already alluded, and which was but a youthful production, I gave my measurements of the solar radiation as taken with a black bulb thermometer in vacuo, and I think it well to repeat them here, because some similar observations made since by the Rev. Mr. Redford, F.M.S., and others, for four years at the hotel Belvedere, have found their way into a very large number of medical publications, although they are entirely incorrect in consequence of the radiation thermometer being placed upon the white screen, thus registering, instead of 100° F., about 120° F., and instead of 120° F. about 140—150° F.

	1870		1871	
	Nov.	Dec.	Jan.	Feb.
Mean of daily Maxima	95·1 F.	73·9 F.	77·3	104·3
Maxima of month	115·4 F.	115·1 F.	117·2	126·0
Mean of the Maxima of Air Temperature, in shade	35·8 F.	41·9 F.	43·8 F.	32·4

too high, causing the readings of any hygrometrical instrument to show too low a percentage of moisture. Some observations made for three years at the Belvedere seem to me of little value on account of being made in a Stevenson's screen exposed to the sun; but on this point I do not now wish to speak too positively, as I purpose shortly comparing all the observations made in Davos in order to find out what screen should be used.

It must not be forgotten that those causes which give us so much solar radiation also bring about great terrestrial radiation. No exact observations have yet been made here on this subject of terrestrial radiation, and as I only had a place very much exposed to the ravages of dogs and children I could not place out a valuable instrument, but put out a cheap minimum thermometer about an inch above the snow, with the bulb painted white, because I considered that in this way the radiation from the snow was best tested. I had it out for about four weeks, when it was stolen. The results were that the mean minimum from the 6th to 28th February inclusive was 5·5° Fahr., which is about thirteen and a half degrees lower than the mean of the minima of the shade temperature, but as the instruments were not absolutely reliable I cannot give the exact difference. This means that on a fine day the difference between the minimum terrestrial and maximum solar radiation is at least 100° F.; on one occasion it was 122·8 degrees. At nine o'clock (viz., before the sun was shining in the valley generally) I registered −3° Fahr. with the radiation thermometer, and at the same time the temperature of the air was 19·2° F. or a difference of 22·2 degrees. I had the opportunity of seeing that thermometers placed, unprotected, on the side of a house, as is so often done by those who take "window observations," gave morning results fairly parallel with these terrestrial observations, and did not give the temperature of the air at all, and it seems that both the exposed Stevenson's screen or a metal box attached to the side of a house, as used by the Swiss, must be very much influenced by terrestrial radiation.*

Mr. Demmer, the intelligent proprietor of the Angleterre Hotel, shortly before my arrival put up a Stevenson's screen in a provisional position, and as soon as he has completed some building and is satisfied as to the best means of protecting the instruments, intends to make some observations. He very kindly allowed me to make some comparisons with the result obtained in my box, and as his instruments were made by Casella and tested in Kew, and those I was using also by Casella, they may be relied upon.

From ten observations made for the purpose, I find that the average range in temperature from 9 a.m. to 1 p.m. is 5 degrees more than I obtained in my shaded box, and upon one occasion the range was 9·2° F. more than mine.

Formula.

But even when we have got the observations correctly taken we are by no means at the end of our difficulties, as the different formulæ used to calculate the moisture from the dry and wet bulbs give materially different results. In England, Glaisher's tables, or Apjohn's formula are mostly used; whereas in Germany and Switzerland tables based on Regnault's formula or the formula itself are used.

In Glaisher's tables we find under dry 36°, wet 30° F., relative moisture, 53 per cent at sea level, whereas Jelinek† for the same temperatures gives 47 per cent. With a very cold and dry air, the difference would be much larger, and the differences of the various formulæ are in some cases increased when we give the correction for diminished baro-

* Prof. H. Wild describes a large wooden screen under which the metal boxes as used in Switzerland can be hung, and probably this would be the most satisfactory plan for Davos. Aufstellung der Thermometer z. Bestimm. d. wahren Lufttemp. Ak. St. Petersburg, 1878.

† Psychrom. Tafeln. für das hundertth. Thermom. von Dr. Jelinek. Wien, 1876.

metrical pressure, though by using Regnault's or Apjohn's original formula the difference is not so very great.

I have, however, noticed that in some papers on high climates presented to the London Meteorological Society, Glaisher's tables have been used without applying any barometrical correction, whereas the tables are arranged for England, and not for a barometrical pressure of 25 inches without correction.

In Dr. C. Theodore Williams' communication "On the Winter climate of Davos," *Meteor. Journ.*, he seems to have taken the mean of the month's temperature of the wet and dry bulb,* and then by the aid of Glaisher's tables without barometrical correction, put down the "relative humidity" obtained from these figures as the month's mean, causing in many cases a very considerable error. For instance, he gives Jan., 1881, from mean temperature of air at 1 p.m. 28·9° F., mean of evaporation 24·6° F., the relative moisture as 40, to which he refers in the text as showing how dry the month was, whereas if he will calculate this out by Apjohn's formula

$$f = f' - \frac{d}{96} \times \frac{h}{30}.$$

he will obtain 60·1, though if he had taken the mean of each day's humidity he would have obtained about 67·0 relative humidity.† It is very unfortunate that anyone of Dr. Williams' medical reputation, and who has written several important things on Davos, should have given his name to a paper where the observations are open to grave doubts, and the calculations made as if Davos was on the sea coast.

I have, however, found that the moisture as calculated

* These figures cannot give the mean humidity correctly, but it must be calculated out for each day, and then the mean of these results given.

† Mr. Muddock's figures of observations taken by the same observers give for Feb., 1880, temperature at 1 p.m. 36·06° F., not 38·4 as given by Dr. W.

by Apjohn's formula is higher than what I have obtained with other instruments this winter. I hear that some important experiments are now being made on various hygrometers, and we may hope that they will result in bringing about greater uniformity than now exists.

Dryness of Air we breathe.

Although it is necessary that the meteorological conditions of the air should be studied, we must not stop there, but must afterwards find what is the influence upon the human organism. I formerly pointed out how much patients could be out of doors in Davos, and extended experience convinces me that they enjoy, in favourable winters, more fresh air out of doors than in warmer resorts, as the Riviera; but this time I will not stop there, for what is also very important, we can enjoy fresh air more in our rooms than in most warm resorts. No doubt it will at first sight seem strange that consumptive patients should sleep with their windows open* where the temperature is 10°, 20°, 30° F., or even more, below freezing point; but consideration will show that it is only reasonable and what we might expect, for with the low temperature the absolute amount of moisture, even were the air saturated, could be but small. Now the cold air entering into the room is rapidly warmed, and as the amount of moisture it contains is a very small proportion of what air at the room temperature can contain, this causes the relative moisture of the room to be very low. I have found this winter that in my room this percentage of the possible moisture has varied from 25°—35° as measured with a hair hygrometer and also with a Regnault's condenser hygrometer. As an example, on January 15th, at 9 a.m., the temperature of the air out of doors was 18° F.

* When I speak of the window being open I do not mean wide open, but one large pane or the top of the window open, and this is enough to keep the air fresh. Much wind prevents this, but fortunately this has been very rare this winter.

and the relative moisture 60°, showing that the air contained 0·7 grains of moisture in a cubic foot. The total quantity which air at 18° F. can contain is 1·2 grains, whereas at 60° F., the temperature of my room, it could contain 5·8 grains; so that air entering with only 0·7 grains would have only 12 relative humidity, but as there is always evaporation going on in my room from the water basin, &c., and also some steam entering from the steam stove which heats the room, the percentage of moisture is raised, and on the occasion referred to the amount actually in my room was 27 rel. humid.

Dr. Volland* made some observations on the amount of moisture in the room, and he obtained much more than I have ever found the case, but it seems to me that this is to be accounted for by his using the wet and dry bulb thermometers, which I find are not at all suitable for room observations, as the stagnation of air is too great. I have found that the temperature of the wet bulb is reduced several degrees by the artificial current produced by waving a newspaper in front of it.

On the Riviera di Levante I dare not sleep with an open window, which is easily understood, because the relative moisture being more at night than in the day, without the temperature outside being very materially below that of the room, we should only be breathing damp air through the night. We now see that in Davos we are not only breathing an absolutely dry air, but also nearly, or all through the 24 hours, a relatively very dry one, in fact, drier than either on the Riviera or Egypt.

Seeing how dry the rooms really are we can easily understand how it is that the general public should form very exaggerated ideas as to the dryness of the place, for even the shopkeepers when they have spoiled old stock try to pass it off by ascribing the changes that have taken place

*Ueber Verdunstung und Insolation, von Dr. Volland. Basel, 1879.

to the dryness of Davos; and many of the medical writers on Davos have been misled in the same way, and give examples which have nothing to do with the dryness of the climate, for instance, the sun shining on the dark roofs or road makes the surface on which it shines extremely warm, and as the warm layer of air is capable of containing much more moisture than the colder air above, the evaporation is extremely rapid, and the roof or road is soon dried, and the moisture rises into a colder air, in fact sometimes this stratum of air is so much colder than that below that it cannot contain as much moisture as exists in the warmer air, and the banks are seen to steam, showing that the ground is warmed by the sun, but by itself not giving any clue as to the amount of moisture in the air. These phenomena, or the rapid drying of ink, or cracking of furniture, have often been used to illustrate the dryness of climates, whereas they really, in such cases, only show the difference of temperature of the room and outside air or the warming of the ground; but these considerations show us that the physiological action of the dryness or dampness of a climate is not a simple one, for as the body is warmer than the surrounding air evaporation must take place more rapidly from the skin than from the evaporometer, and the difference will be more marked, *cœteris paribus*, when the quantity of absolute moisture is small, that is, when the air is cold.

In the same way cold air entering the lungs is raised to a temperature approaching blood heat; now this cold air may be relatively moist, but the absolute moisture which it contains is but small, so that when raised to nearly blood heat it would be very dry, which means that it can absorb a great deal of moisture, which will be the case, and it will carry off a large quantity from the lungs. An example will make this clearer. Supposing that the air breathed at the sea level is 20° F., and contains 80 per cent of the possible moisture required for saturation, this will be raised in the lungs to something like 85° F., viz., a few degrees lower than the blood heat; at that temperature it can contain about ten times as much moisture as it could at 20° F., and will, therefore, carry off a large part of this amount from the lungs; or to put this another way, the amount of evaporation from the lungs will now be much the same physically as if we breathed air of 85° F. only containing about nine per cent relative moisture. This has already been pointed out by Brunner, Krieger, &c.; and Mr. Steffen, the chemist here, published some tables, in which he reduced the moisture in the air to the relative of the mean blood heat (37° Cel.), that is, he showed for each month what per cent of the quantity which air could contain at 37° C. was present in the atmosphere.* It seems to me that the principle thus dealt with is undoubtedly correct, but I think that the figures require modification, because, as pointed out by Dr. Volland, it is taken for granted that the air was raised to blood heat and expired saturated, neither of which are absolutely correct. I hope to enter more fully into this point when I have had the opportunity of collecting more data, and seeing what has been written on the subject.

We must not forget that the physiological feeling of cold depends, to a large extent, upon evaporation, for perspiration is always taking place from the surface of the body, though we only notice it when it is abnormally great, and upon the rapidity with which this is removed hangs to a large extent our sensation of the air being dry or cold. We have already seen that the evaporation from the skin is, as a rule, great in Davos, and to this cause must, to a large extent, be attributed our sensation of the dryness of the atmosphere.

* Die Meteorologische Verhaltnisse von Davos von W. Steffen. Basel, 1878.

Wind.

The next point is the amount of wind. It has always been maintained that there is very little wind in the valley in winter, but as bare statements on such a subject are not often satisfactory, I put up a Robinson's anemometer. I was not able to find an altogether suitable place, for on the roof of a house we might measure the valley wind, but this would have very little meteorological value, and none physiologically, besides which the instrument would soon have been clogged with smoke. I therefore decided to put it up just over 5ft. 5in. above the ground, in a position quite open to the north and south, but unfortunately somewhat protected by a building (160 feet way) from the south-west wind, of which we have had little this winter. A building on the W.N.W. (120 feet away) did not make any difference, as the wind in this spot never blows from that direction. In a valley the wind often varies very much within short distances, both in direction and force, but I think we may say that my instrument would fairly show the force of wind to which a patient was exposed in taking an ordinary walk. As the value of these observations were physiological, I noted down the movement at 9 a.m. and 3 p.m., thus getting our winter day; and as the valley wind rises in the afternoon, I also observed, with a few exceptions, at 1 p.m. I have not yet applied the correction for diminished barometrical pressure, but give the figures as registered, but thus unrevised. The total movement was for—

	Total. Miles.		Day. From 9 to 3: 6 hours.		Night. From 3 to 9: 18 hours.
November, 1881	561·69	...	—	...	—
December	727·99	...	256·14	...	471·85
January, 1882	283·76	...	77·95	...	205·81
February	597·92	...	290·95	...	306·97
March	1656·61	...	—	...	—
April (to 24th)	1439·59	...	—	...	—
			625·04		984·63

The result of the 89 days of December, January, and February (during this time the ground was more or less covered with snow when I went to my instrument at 1 p.m.), shows that the mean rate from 9—1 was 0·608 miles per hour, while from 1 to 3 p.m. it was 1·384 miles per hour; that is to say that about one-fifth of the wind which blew in the 24 hours was between 1 to 3 p.m., and nearly all of this will be a valley wind*; and to return to what I before said, this will mean that the same air may be blown backwards and forwards two or three times over Davos, and thus there are great dangers from any drainage carried into the river within a few miles of the principal village.

Smoke.

There is another thing which I must mention, though not belonging to any series of observations, but when here before I frequently had occasion to examine the snow and smoke microscopically, and at that time the snow really remained white, and when filtered, hardly gave any deposit, as the combustion from the stoves was very perfect and nearly all the smoke was microscopic, consisting of small particles, in which wood structure could often be seen, but now all is changed, for when I filtered snow water to use it for evaporation, the filter soon became quite black, and so far choked up the filter as to allow the water to pass through but very slowly.

The large amount of smoke which falls upon the snow is to a large extent masked, because in our fine weather the snow entirely recrystallises down to the ground, within a

* This winter has been generally still in this district of Switzerland, that possibly there is usually more wind than this winter, but we can see that it is as a rule but little. The ground was free of snow most of March, and therefore the valley wind was stronger.

Out of 293 times that I went to the anemometer during the three winter months, there was no movement at all on 208 occasions (71 per cent).

At 9 a.m. it was	16 times moving	and	74	still.	
At 1 p.m.	do.	20	do.	59	do.
At 3 p.m.	do.	44	do.	45	do.

few days of falling, and each night the upper crystals grow very much through the deposit of hoar frost. In the lower part of the valley, especially near the river, these arborescent crystals grow to be sometimes two inches long or even more, while on the sides of the hill they are but small. This test as to the amount of moisture in the air shows how much more healthy the higher positions must be. These crystals, however, grow on the surface, so that the smoke is no longer visible, but when a thaw comes then, in comparison to what it was twelve years ago, it may around the village be called black, though of course in comparison with that in a large English town we should have to call it white.*

The Curverein, in their German answer to Mr. Symonds, replied that what he said about the smoke could not be true, as the snow crystals glittered, but as the English translation in the *Pall Mall* was very much modified on this point, it would seem that a thaw in the meantime must have shown the writers the absolute incorrectness of what they had said.†

* I should have been glad to have had some exact observations on the amount of smoke, but I did not see the importance of this until too late. I then wrote to my friend Professor F. Clowes, who kindly sent me weighed filter papers, but there has not been a favourable opportunity since. However, I sent Professor Clowes one of my larger used filter papers, and he removed the dirt, which will be almost all smoke to a weighed paper. I filled my tin, Feb. 20th, with 1300 grammes of snow, which must have fallen on the 19th, and when put into the tin looked quite clean. It was hung in my meteorological screen until the 23rd. The dirt thus removed, and weighed by Professor Clowes in the manner, mentioned, was 0·082 gramme.

If I had taken this snow from an area three times the size of my tin, which is an ample allowance, we should find that the amount of the dirt—mostly smoke—which falls in the large Curhaus garden, amounts in a few days to half a hundred weight. The position of the tin was nearly due south of the large chimney, which is situated 330 feet away. More exact observations on this point would be valuable.

† Besides the observations mentioned, I have a few temperature measurements, made with the thermometer in the snow, or placed above it; and further, I have a series, from various visitors, of about 3,000 measurements of the blood temperature taken at fixed times, in order to study the physiological action of weather. These will take some time to work up, and will be dealt with in a separate communication.

There is one most important point which is sure to receive very different judgments, and that is how the patients are to be amused, and perhaps those who know that various investigations give me constant employment in my own room, may think that therefore I do not understand its importance, whereas on the contrary I should place it above all other medical treatment, and appreciate how difficult it is to strike the happy mean by which people shall be amused by taking part in amusements without these being on so large a scale as to cause fatigue. For my own part, I often feel that though my devotion to science causes me sometimes to risk my health, yet from the health point of view I am amply repaid by being enabled, in the non-vitiated air of my own room, to ever find new interests and never experience ennui instead of requiring to frequent crowded salons and theatres, and breathe the second-hand breath of 100 to 200 consumptive patients, but the work which to me is a source of health, would to another be a great danger, and so long as we are so differently constituted, and in different stages of illness, no rule can be laid down for relaxation. And this leads me back to the starting point, and I wish to lay stress on my introductory remarks being a strong warning against the overgrowth of Davos, and do not wish them to be interpreted into meaning that Davos is ruined, for what is meant is that Davos MUST not grow any bigger. It would perhaps be presumptuous to say that it can never grow, for possibly in the next 10 or 20 years the great smoke producers—at the head of which stands the Curhaus, followed by the next largest hotel in the village—may have been taught that they have been very uneconomical, and that there is no necessity to pour so much smoke into the air, and also some earth system may have solved the drainage difficulty and allow a limited increase.

PHYSICAL AND MATHEMATICAL SECTION.

January 31st, 1882.

JOSEPH BAXENDELL, President of the Section, in the Chair.

Mr. W. H. Johnson, B.Sc., and Mr. William Thomson, F.R.S.E., F.C.S., were elected members of the Section.

February 14th, 1882.

ALFRED BROTHERS, F.R.A.S., in the Chair.

"Notes on the Variable Stars U Canis Minoris, V Geminorum, and U Bootis," by JOSEPH BAXENDELL, F.R.A.S.

In a communication to the Section on April 13th, 1880, I announced the discovery of three new variable stars—the first in Canis minor, the second in Gemini, and the third in Bootes. The observations which I have since made, though much less numerous than I could have wished owing to ill health and unfavourable weather, have been sufficient to enable me to ascertain the nature and extent of the changes of brightness and to deduce approximate elements.

U Canis Minoris.

1855·0. $\alpha = 7\text{h. } 33\text{m. } 27{\cdot}5\text{s.}$ $\delta = +8° \ 42{\cdot}9'$.

A projection of the observations of this star shows that it has a double period, but unlike the other known double-period variables in which the sub-periods are nearly if not quite equal, in this they are very unequal.

The times of four minima and three maxima have been obtained and are as follows :—

Principal Minima :

1880, September 27.

1881, November 17.

Secondary Minima :

1880, January 14.

1881, March 11.

Maxima :

1880, February 24.

„ December 27.

1881, April 29.

The secondary minima give the period = 422 days.

The principal „ „ = 416 „

The maxima of Feb. 24, 1880, and Apl. 29, 1881 = 430 days.

The mean period is therefore about 423 days.

The interval from the principal to the secondary minimum is 169 days, and from the secondary to the principal minimum 254 days.

The highest maximum magnitude yet observed is 8·5, and the lowest minimum 13·0; the range of variation being therefore 4·5 magnitude.

V. Geminorum.

1855·0. $\alpha = 7^h.\ 15^m.\ 2^s.$ $\delta = +13°\ 21{\cdot}9'$.

My observations of this star have yielded the times of two maxima and two minima as follows :—

Maxima :

1880, February 6.

„ November 9.

Minima :

1881, March 28.

„ December 28.

The maxima give the period = 277 days, and the minima = 275. The mean period is therefore about 276 days.

The highest observed magnitude at maximum is 8·7. At minimum the star falls below 13·5 magnitude.

U Bootis.

1855·0. $\alpha = 14^h. 47^m. 37 \cdot 4^s.$ $\delta = +18° 17 \cdot 1'$.

This variable is more regular in its changes than either U Canis minoris or V Geminorum, and its period much shorter. The observed maxima and minima are as follows:—

Maxima :

1880, March 22.
„ September 15.
1881, August 31.

Minima :

1880, June 11.
1881, May 31.

It was equal to 11·5 magnitude when decreasing.

1880, May 5.
„ October 29.
1881, April 23.
„ October 14.

And equal to 11·5 magnitude when increasing.

1880, July 22.
1881, July 4.

The mean period derived from the above data is 175·5 days; and the mean interval from minimum to maximum is 94·0 days; and from maximum to minimum 81·5 days. A maximum may be expected to occur about August 17, 1882.

The highest observed magnitude at maximum is 9·15, and the lowest at minimum 13·6, the extreme range of variation being therefore 4·45 magnitude.

Mr. J. A. Bennion, B.A., F.R.A.S., read a paper "On the Resolution into Factors of some Trigonometrical Expressions without using imaginaries."

Annual Meeting, March 14th, 1882.

Joseph Baxendell, President of the Section, in the Chair.

The following gentlemen were elected Officers of the Section for the ensuing year.

President.

JOSEPH BAXENDELL, F.R.A.S., &c.

Vice-Presidents.

J. P. JOULE, LL.D., D.C.L., F.R.S., F.C.S.
A. BROTHERS, F.R.A.S.

Secretary.

J. A. BENNION, B.A., F.R.A.S.

Treasurer.

JAMES BOTTOMLEY, D.Sc., B.A., F.C.S.

Mr. Brothers, F.R.A.S., showed a diagram of the Barometric Oscillations for the year 1881.

Mr. W. H. Johnson, B.Sc., exhibited several electric lamps, some of which were intended for use in Collieries.

"Notes of some Experiments made in February, 1881, on the Influence of Stress on the Electrical Resistance of Iron and Steel Wires," by Wm. H. Johnson, B.Sc.

A piece of piano steel wire, about 0·040 inch diameter, was found to have a resistance of 0·418 Ohms. A heavy longitudinal stress causing a temporary elongation of 3 %, but not sufficient to produce any permanent strain, was applied, and the resistance observed was 0·422 Ohms, the temperature in both cases being the same.

If the resistance per meter gramme of the wire had been unaltered by the *stress*, the observed resistance of the wire under stress should have been 0·443 Ohms, or some 5 % more than that observed.

The resistance of hardened and tempered steel wire thus appears to *decrease* 5 % under stress.

Experiments were next made on hard iron wire, about the same diameter as above, 1·774 meters long and 0·2274 Ohms resistance. Under longitudinal stress, causing a temporary elongation of 0·33 %, the resistance was found to be 0·232 Ohms. Now, if the wire had been unaltered in resistance by stress, the observed resistance should have been 0·229 Ohms. Thus it appears that the resistance of hard or unannealed iron wire, unlike piano steel, is *increased* by stress some 1½ %.

The figures denoting the percentage of change of resistance caused by stress are of course only approximate, but serve well to denote the direction of the change.

In both sets of experiments the iron and steel wires returned to their original resistance when the stress was removed.

The stress applied to the steel wire was many times that applied to the iron wire, so it is just possible that the steel wire under a small stress would have behaved like the iron wire and increased in resistance. The stress applied to both iron and steel wires was the highest they would bear without permanent change of length.

The writer has long intended to continue these investigations, but hitherto time has failed him, and he now only publishes them as he sees from an abstract of the Pro. Royal Society, January 26th, that Mr. H. Tomlimson, B.A., has been experimenting in the same direction.

Dr. BOTTOMLEY pointed out an analogy between the circle and the logarithmic spiral, and showed how some properties of the former curve could be derived from the latter.

"On the Projection of a Solid on Three Coordinate Planes," by JAMES BOTTOMLEY, D.Sc., B.A., F.C.S.

Take a solid of any form and let sections be made by parallel planes fixed in the solid. Let L be the longest axis of the solid which is perpendicular to these planes. This axis and these planes we may call the primitive axis and the primitive planes.

Let the primitive axis make with the axes of x, y, z angles a, β, γ respectively. Consider a section whose area is A_1. If this be projected on the plane xy the area of the projection will be $A_1\cos\gamma$. This projection we may denote by A_{z1}. So in like manner the projections on the other planes will be $A_1\cos\beta$ and $A_1\cos a$, and may be denoted by A_{y1}, A_{x1}. The projections of a second area A_2 will be $A_2\cos\gamma$, $A_2\cos\beta$, $A_2\cos a$, and may be denoted by A_{z2}, A_{y2}, A_{x2}. Let the remaining planes be projected in the same manner. Then by addition we shall have

$$A_{z1} + A_{z2} + \ . \ . \ . \ A_{zn} = \cos\gamma(A_1 + A_2 + \ . \ . \ . \ An) \quad \text{.........}(1)$$

$$A_{y1} + A_{y2} + \ . \ . \ . \ A_{yn} = \cos\beta(A_1 + A_2 + \ . \ . \ . \ An) \quad \text{.........}(2)$$

$$A_{x1} + A_{x2} + \ . \ . \ . \ A_{xn} = \cos a(A_1 + A_2 + \ . \ . \ . \ An) \quad \text{.........}(3)$$

Let Z be the projection of the line L on the axis of z; also suppose that there are n sections. Then equation (1) may be written

$$\frac{A_{z1}+A_{z2}+\ \ldots\ A_{zn}}{Z}\cdot\frac{Z}{n}=\cos\gamma\frac{(A_1+A_2+\ \ldots\ An)}{L}\cdot\frac{L}{n}$$

or more briefly

$$\frac{1}{Z}\Sigma A_z\Delta Z=\frac{\cos\gamma}{L}\Sigma A\Delta L \text{ ....(4)}$$

when ΔZ and ΔL have been written for $\frac{Z}{n}$ and $\frac{L}{n}$ respectively. Operating in a similar manner on equations (2) and (3) we shall have

$$\frac{1}{Y}\Sigma A_y\Delta Y=\frac{\cos\beta}{L}\Sigma A\Delta L \text{ ....(5)}$$

$$\frac{1}{X}\Sigma A_x\Delta X=\frac{\cos\alpha}{L}\Sigma A\Delta L \text{ ....(6)}$$

Now suppose n to become indefinitely large, then the limits of the expressions (4), (5), (6) are

$$\frac{1}{Z}\int_0^Z A_z dZ=\frac{\cos\gamma}{L}\int_0^L A dL \text{ ....(7)}$$

$$\frac{1}{Y}\int_0^Y A_y dY=\frac{\cos\beta}{L}\int_0^L A dL \text{ ....(8)}$$

$$\frac{1}{X}\int_0^X Ax dX=\frac{\cos\alpha}{L}\int_0^L A dL \text{ ....(9)}$$

Now suppose a solid to be constructed whose axis is perpendicular to the plane of xy and of length Z and whose sections parallel to the same plane are A_{z1}, A_{z2}, &c. Let the volume of this solid be V_z. Let similar solids be constructed whose axes are Y and X. Let these be denoted by V_y, V_x, then we shall have

$$V_z=\int_0^Z A_z dZ \text{ ....(10)}$$

$$V_y=\int_0^Y A_y dY \text{ ....(11)}$$

$$V_x = \int_0^X A_x dX \quad \text{..........................} (12)$$

Substituting these values in (7), (8), (9), we obtain

$$\frac{V_z}{Z} = \frac{\cos\gamma V}{L} \quad \text{..........................} (13)$$

$$\frac{V_y}{Y} = \frac{\cos\beta V}{L} \quad \text{..........................} (14)$$

$$\frac{V_x}{X} = \frac{\cos\alpha V}{L} \quad \text{..........................} (15)$$

where V has been written for $\int_0^L A dL$ and denotes the volume of the primitive solid which is, of course, a constant. Since X, Y, Z are the projections of L on the coordinate axes we shall have

$$X - L\cos\alpha$$

$$Y = L\cos\beta$$

$$Z = L\cos\gamma$$

Substituting in (13), (14), (15) the resulting equations will be

$$V_z = \cos^2\gamma V$$

$$V_y = \cos^2\beta V$$

$$V_x = \cos^2\alpha V$$

adding and remembering that $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$, we obtain

$$V_z + V_y + V_x = V$$

Hence if we suppose the original solid to move in any way, the volume of each projected solid will vary, but the sum of these volumes will be always constant and equal to the volume of the original solid.

If the primitive axis at any time should be perpendicular to one of the coordinate planes, then of the three quantities V_x, V_y, V_z two will vanish, and the remaining one will be a solid equal and similar to the original solid.

As an example, consider a sphere, the diameter of which is 2R, and let the direction angles of the primitive diameter be a, β, γ, and let the sphere be divided into sections perpendicular to this diameter. Consider one of these sections whose radius is r, let l be the length of the diameter intercepted between this section and the lower part of the sphere, then we shall have

$$r^2 = 2Rl - l^2 \quad \text{.........................(16)}$$

The circular section projected on the plane xy will be an ellipse whose semi-axes are r and $r\cos\gamma$, the area of this ellipse will be $\pi r^2 \cos\gamma$; hence we have

$$V_z = \pi\cos\gamma \int_0^Z r^2 dz \quad \text{.........................(17)}$$

z is the projection of the line l on the axis of z. Therefore

$$z = l\cos\gamma$$

Substituting this value of l in (16) we obtain

$$r^2 = 2R\frac{z}{\cos\gamma} - \frac{z^2}{\cos^2\gamma}$$

and substituting this value of r^2 in (17) we obtain

$$V_z = \pi\int_0^{2R\cos\gamma}\left(2Rz - \frac{z^2}{\cos\gamma}\right)dz$$

In a similar manner we may obtain

$$V_y = \pi\int_0^{2R\cos\beta}\left(2Ry - \frac{y^2}{\cos\beta}\right)dy$$

$$V_x = \pi\int_0^{2R\cos\alpha}\left(2Rx - \frac{x^2}{\cos\alpha}\right)dx$$

Performing the integrations we obtain

$$V_z = \tfrac{4}{3}\pi R^3\cos^2\gamma$$

$$V_y = \tfrac{4}{3}\pi R^3\cos^2\beta$$

$$V_x = \tfrac{4}{3}\pi R^3\cos^2\alpha$$

By addition we get

$$V_z + V_y + V_x = \tfrac{4}{3}\pi R^3$$

or the sum of the three projections is equal to the volume of the sphere. In this case the three component solids are three spheroids whose semi-axes are respectively R, $R\cos\alpha$, $R\cos\alpha$; R, $R\cos\beta$, $R\cos\beta$; R, $R\cos\gamma$, $R\cos\gamma$.

PROCEEDINGS

OF THE

MANCHESTER

LITERARY AND PHILOSOPHICAL SOCIETY.

VOL. XXII.

SESSION 1882-83.

MANCHESTER:
PRINTED BY T. SOWLER AND CO., 24, CANNON STREET.
1883.

NOTE.

The object which the Society have in view in publishing their Proceedings is to give an immediate and succinct account of the scientific and other business transacted at their meetings to the members and the general public. The various communications are supplied by the authors themselves, who are alone responsible for the facts and reasonings contained therein.

INDEX.

PROCEEDINGS

OF THE

MANCHESTER

LITERARY AND PHILOSOPHICAL SOCIETY.

Ordinary Meeting, October 3rd, 1882.

H. E. Roscoe, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

Dr. R. Angus Smith, F.R.S., showed a vitrified mass of stone, and gave the following description:—I went up lately to Fort William to see Mr. Wragge, who is making observations on the comparative amount of sunlight on the top of Ben Nevis and on the shore at his house, after a method advised by me, and, as usual, I amused myself with a little archæology. I had seen in a recent map the vitrified Fort of Glen Nevis called by the strange name Dornadilla, a name that is found among Boece's Kings of Scotland, but not hitherto applied to this fort as I supposed. I went up the glen to refresh my view of the site, and saw the line of the fort looking down. The glen is very grand. The fort stands on the south looking to the precipitous sides of Ben Nevis and down the glens both north and south. One of its objects was evidently to watch. The name of this fort, along with two or more of the same kind, is Dun Deardhuil, which the Rev. Dr. Clerk, of Kilmallie, says may mean "The Fort of the shining eye." This name anglicised by Macpherson into Darthula is that given to the great beauty of the western Celts, the Ulster Lady, called in Ireland Deirdre. She was the "Helen" of the race, and her history and its indirect consequences brought out the Iliad of Ireland, but I am one of the many who cannot give an opinion of the work. The similarity of name and the fact that Deirdre came over to Loch Etive may have caused people to connect these forts with her, but the fact of their being places of security requiring also vigilance is a reason for connecting them with the "shining eye," a name, too, that may be easily supposed applicable to Deirdre. She was vigilant and beautiful. They were vigilant, but not beautiful. The work of the forts is rough; shapeless and small stones are melted together by a rude glaze. All known to me are walled enclosures. The only one with any very distinct connection with history or legend contained a dwelling with apartments; it is described in "Loch Etive and the Sons of Uisnach." The glazing or cementing is done systematically, and instead of using mortar. I have published elsewhere the analysis of one piece from Loch Etive, and my youngest assistant, Mr. Frank Scudder, has analysed the fused part of this from Glen Nevis with the following results:—

	Per cent.
Silica - - - - -	68·88.
Alumina - - - - -	16·17.
Iron - - - - -	5·33.
Lime - - - - -	3·73.
Magnesia - - - -	3·39.
Potash - - - - -	1·83.
Soda - - - - -	0·26.
Loss on ignition - - -	0·92.
	100·51.

The walls of some show enormous masses of vitrified matter. One, the "Tap o' Noath," in Aberdeenshire, is a remarkable example, the enclosure is great, and so is the debris; it is on a hill, seeking however to be retired, one would think. At St. Brieuc in Brittany, one greater still is on a flat. There are about fifty in Scotland, two or three in Ireland, at least one in Bohemia, more than that in France, and we hear a whisper of one in the valley of the Euphrates and elsewhere in Asia. Their first home is still to find. I look to the east for them, and think that they entered Scotland by the east. I hope no one will without good authority put new names into maps. The first statistical account writes Dundhairdghall, but many letters are silent in Gaelic, and at any rate I leave that to others to explain if they think it not simply an instance of insertion of a guttural, common to speakers of Gaelic in many places.

Mr. R. F. Gwyther, M.A., described a compound rainbow he had seen in Scotland last summer, in which, besides the ordinary primary and secondary bows, a portion of a third was seen crossing the interval between the two, and extending a little beyond the outer border of the secondary.

Dr. Schuster, F.R.S., gave an account of some of the results of an examination of the photographs of the solar corona he had taken in Egypt during the eclipse of May last.

General Meeting, October 17th, 1882.

H. E. Roscoe, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

Mr. Henry Holt, of Palatine Road, Didsbury, was elected an Ordinary Member of the Society.

Ordinary Meeting, October 17th, 1882.

H. E. ROSCOE, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

"On the Development of Living Germs in Water," by Dr. R. ANGUS SMITH, F.R.S.

An abstract of this paper will appear in a succeeding number of the Proceedings.

Mr. WILLIAM H. JOHNSON, B.Sc., in the absence of Mr. LEADER WILLIAMS, C.E., gave an explanation of the plans of the proposed Manchester and Liverpool Ship Canal.

"On the Formula for the Intensity of Light transmitted through an Absorbing Medium, as deduced from Experiment," by JAMES BOTTOMLEY, B.A., D.Sc.

In a former communication, an experimental method was suggested for testing the validity of an assumed law of intensity of light that has passed through an absorbing medium. The method was this: take two surfaces of different degrees of brightness, survey them through some absorbing medium, adjust the lengths of the columns so that the intensities shall be the same; then, if the law of absorption be true, the intensities will again be equal if both columns are increased by the same length. Some experiments which I made gave results in agreement with the theory. In these experiments surfaces of different degrees of whiteness were observed through a grey solution. The error arising from the finite extent of the surface is small, and the mean intensity which we observe may be taken as the intensity of the central ray.

But suppose we had started with no hypothesis as to the form of the function expressing the intensity of transmitted light, but had found as an experimental result that when the intensities are equal they remain equal when the columns receive equal increments; what form for the function might be deduced from such a result?

Suppose there are two lights of initial brightness I_o and I_o' respectively, then if x and y be the lengths of the absorbing columns, for the transmitted light in one case we shall have

$$I_x = I_o\phi(x) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

and in the other case

$$Iy = I_o'\phi(y) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

ϕ being the unknown function which it is required to determine. Since these two intensities are equal,

$$I_o\phi(x) = I_o'\phi(y) \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

If both columns receive an equal increment, the intensities will again be equal. Let this common increment be denoted by κ, then:

$$I_o\phi(x+\kappa) = I_o'\phi(y+\kappa) \ldots\ldots\ldots\ldots\ldots(4)$$

These equations will still hold if $y=o$. In this case the duller surface is observed directly, and the length of the absorbing column over the brighter surface is increased until they are brought to the same intensity. Since when $y=o$ $I_y'=I_o'$, therefore $\phi(o)=1$.

Equations (3) and (4) will become

$$I_o\phi(x) = I_o' \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$I_o\phi(x+\kappa) = I_o'\phi(\kappa) \quad \ldots\ldots\ldots\ldots\ldots(6)$$

Expand (6) in terms of κ

$$I_o\{\phi(x) + \frac{d\phi(x)}{dx}\kappa + \frac{d^2\phi(x)}{2dx^2}\kappa^2 + \&c.\} = I_o'(1 + \phi'(o)\kappa + \frac{\phi''(o)}{2}\kappa^2 + \&c.)$$

Since the first terms of the expansions on each side are equal, the equation may be written

$$I_o\left(\frac{d\phi x}{dx}\kappa + \frac{d^2\phi x}{2dx^2}\kappa^2 + \&c.\right) = I_o'\left(\phi'(o)\kappa + \frac{\phi''(o)\kappa^2}{2}\kappa^2 + \&c.\right)$$

Dividing both sides by κ and diminishing κ without limit, the resulting equation will be

$$I_o \frac{d\phi(x)}{dx} = I_o{}'\phi'(o)$$

Eliminating $\quad I_o$ and $I_o{}'$ by (5)

$$\frac{d\phi(x)}{dx} = \phi'(o)\phi(x)$$

the integral of this is

$$\log\phi(x) = \phi'(o)x + c$$

or

$$\phi(x) = Ce^{\phi^1(o)x}$$

when $x = o \quad \phi(x) = 1$

Therefore $\quad C = 1$

Also as x increases the intensity diminishes, therefore $\phi'(o)$ must be some negative constant, let it be denoted by $-m$. Then the equation becomes

$$\phi(x) = e^{-mx}$$

and equation (1) may be written

$$I_x = I_o e^{-mx}$$

Hence experiment leads to the same form for the function as the hypothetical form with which we started.

If in the above investigation we had made the length of the column invariable, and x denoted a mass of some colouring matter which undergoes no decomposition on dilution, we might have obtained experimentally the form of the function expressing the intensity of the light transmitted through a column of fluid of invariable length containing a variable quantity of colouring matter.

In the above remarks I have supposed we are dealing with homogeneous light or with white light which has penetrated a medium containing soluble black in solution. To apply the formulæ generally we must prefix to them the sign of summation.

In seeking *a priori* the law of transmitted light we might have reasoned as follows, which involves less assumption than Herschel's reasoning:—Suppose we have a column of any length, conceive it divided anywhere into two lengths, x and y, by an imaginary plane. Let I_o be the initial intensity of light; after penetrating the column x we shall have

$$I_x = I_o\phi(x).$$

But if light of intensity I_x penetrate a column of length y, the transmitted light will be $I_x\phi(y)$, or by substitution $I_o\phi(x)\phi(y)$. This will be the intensity after penetrating the whole column, since the length of the column is $x+y$, the emergent light will also be expressed by $I_o\phi(x+y)$, equating these two expressions for the same quantity there results

$$\phi(x)\phi(y) = \phi(x+y).$$

It is well known that this functional equation is satisfied by an exponential form.

I may also take this opportunity to correct some errors in Colorimetry, part II., contained in vol. XIX. of the Proceedings.

			c.	c.
Page 41	line 31	for 6000	read 6014.	
,,	,, 32	insert "nearly" before the theoretical column.		
43	,, 20	for 600 read 6000.		
,,	,, 23	for 6682 read 6652.		
46	,, 20	for 17·9 read 9.		
,,	,, 22	for 5·2 read 5·1.		
,,	,, 26	for former read "latter" and for latter "former."		
,,	,, 27	for $1600\ (17+x) = 2400 \times 21{\cdot}2$ read $1600\ (21{\cdot}2+x) = 2400 \times 17$.		

"On the Intensity of Light that has been transmitted through an Absorbing Medium in which the Density of the Colouring Matter is a function of the distance traversed," by James Bottomley, B.A., D.Sc.

In previous papers it has been supposed that the absorbing matter was uniformly distributed throughout the medium. In the present paper the author treats of the intensity of light which has passed through a medium of variable density. Such cases occur in nature, for instance, the atmosphere increases in density as we approach the earth, also we might have coloured glass in which the colouring matter is not uniformly distributed, or the case of a coloured soluble salt on which water is poured, the colour in the immediate vicinity of the salt is most intense and gradually fades as the distance increases. Also the same reasoning would apply very approximately to the case of fluids containing in suspension layers of different density of finely divided matter, or to the case of an atmosphere containing fine dust in suspension. For simplicity it is supposed that we are dealing with homogeneous light, or with white light which has passed through a grey solution. Suppose a ray of light has penetrated a length t of a medium which is not homogeneous and that its intensity is I when it falls on a surface for which the coefficient of transmission is ϵ^{-m}, consider a plate of thickness $\triangle t$ and let $\epsilon^{-(m+\triangle m)}$ be the coefficient of transmission at the upper surface. Let I′ be the intensity of the light emergent from this surface. Then

$$I' < I\epsilon^{-m\triangle t}$$
$$> I\epsilon^{-(m+\triangle m)\triangle t}$$

If we expand the exponentials and write $\triangle I$ for $I' - I$ there results

$$\frac{\triangle I}{I} < -m\triangle t + \frac{m^2\triangle t^2}{2} + \&c.$$

$$> -(m+\triangle m)\triangle t + \frac{(m+\triangle m)^2}{2}\triangle t^2 + \&c.$$

Proceeding to the limit, there results

$$d\log I = -m dt \quad \text{.....................(1)}$$

Now suppose light to penetrate a unit length of an absorbing medium containing q units of colouring matter, there results the following relationship

$$\epsilon^{-m} = \epsilon^{-\mu q}$$

μ being a constant, therefore

$$m = \mu q$$

and equation (1) becomes

$$d\log I = -\mu q dt \quad \text{.....................(2)}$$

For q we may substitute d where d denotes the density of the colouring matter, the unit of density being that due to the distribution of the unit mass through the unit volume.

Now suppose d to vary and to be some function of t, so that

$$d = \phi(t)$$

Let $\chi(t)$ be the integral of this, so that

$$\chi(t) = \int \phi(t) dt.$$

Substituting in equation (2) and integrating, we get

$$\log I = -\mu\chi(t) + C$$

or as it may be written

$$I = C\epsilon^{-\mu\chi(t)} \quad \text{.....................(3)}$$

To determine the constant we must know simultaneous values of I and t. The above equation (3) is the general equation for determining the intensity of transmitted light when the density is an assigned function of the distance traversed. The remainder of the paper is taken up with special cases of this general fromula. Firstly, when the density varies as the distance from the plane of incidence. Secondly, when the absorbing medium is an elastic fluid surrounding an attracting sphere, the law of attraction being that of the inverse square. Thirdly, when the colouring matter is so distributed as to give recurring values of the density, taking as a particular case the relation

$$d = m - n\sin t$$

m and n being constants and m greater than n, as t varies we obtain periodic values of d. In this case the curve of intensity is represented by a sinuous curve always situated between two logarithmic curves and touching them alternately. Finally, it is shown that the general equation may be serviceable for solving inverse questions, such as what must be the law of density in order that the intensity of the light may be a given function of the distance traversed. As a particular instance, the density is determined in order that the intensity may vary as the inverse nth power of the distance.

"The Death-age in Langwies (Switzerland)," drawn up by ARTHUR WM. WATERS, F.G.S., F.L.S.

Many visitors feeling that the growth of Davos has been too rapid, have been anxious to see other places similarly situated, at a high level, tried as winter resorts for consumptive patients, and many competent authorities have thought that the position of Arosa (6000 feet) at the upper end of the Schanfigg valley was very favourable. I therefore went over this spring to see it.

When visiting it I took the opportunity of drawing up a table of the age at death in Langwies (4519 feet above sea level), a village at the lower end of the Schanfigg valley. This Schanfigg valley is parallel with the valley of Davos and also with the Engadine, and as I some years ago published the death age of the inhabitants of Davos (Klimatolog. Notizen ü. Winter im Hochgebrige, Basel 1871) and Dr. Ludwig published those of the Engadine (Das Oberengadin von Dr. J. M. Ludwig, 1877), we have now figures for these three neighbouring valleys.

I only used the figures since 1800 A.D., because the ages in the last century did not seem to have been kept with quite as much fulness as lately.

With regard to Davos I quote a second table which is the more valuable (although only relating to a smaller number) on account of the first table containing the register of a few who died away from Davos.

There has never been a resident doctor in the whole of the Schanfigg valley, but this summer a Swiss medical man has gone there for twelve months on account of an invalid wife.

The tables placed together for comparison are—

630 deaths Langwies, from 1800–1882 (exclusive 34 still-born)		1099 deaths Davos Valley from 1837–1870.	271 deaths Davos Platz 1837–1870.	590 deaths Engadine (Dr. Ludwig) 1861–1870 exclusive of invalid visitors	General average age in Europe (Oesterlen Hand. Med. statistik). p. 156, &c.
0·5	27·77	22·7	20·	22·3	25—45
5·10	3·17	3·1	3·3	2·5	
10·20	3·65	4·6	4·5	3·0	5—6
20·30	4·76	6·2	3·8	4·1	5—6
30·40	5·08	5·0	5·6	5·4	6—7
40·50	7·14	6·6	8·5	7·0	7—8
50·60	10·16	9·4	7·8	13·1	8—9
60·70	16·98	14·9	15·5	16·	9—12
70·80	15·24	17·9	20·3	15·5	8—10
80·90	5·73	8·9	10·	10·	4—5
90·	·32	0·7	0·7	1·2	0·4—0·6

This means that the mean age in Langwies is 48 years, whereas in England it is 36·92 years, and it will be noticed that during the years of youth, viz., the most fatal time for lung disease, the death rate is favourable, and the proportion of those who live to a considerable age is also high.

I may take this opportunity of pointing out that although Arosa is not yet in a position to become a winter resort, there seems every reason to believe that in one or two years the experiment of wintering can be made, and if successful it will shortly be able to relieve Davos of 200 or 300 of its surplus winter patients. At present the difficulty is the want of a road, but Arosa is willing to contribute a reasonable share, and no doubt Chur and other interested places will soon be brought to contribute the rest. We must, however, remember that it is only about seven years since a road was made from Chur to Langwies, and we must therefore not much wonder that a district which is not wealthy has not yet extended it.*

A very small hotel for summer visitors from Chur was built about 4 years ago, and this year another small hotel is being built and will be ready next spring, besides which the ground is marked out for a third, so that there are already indications that the place is likely to grow.

I have good reason to believe that the statement made by those in the neighbourhood that Arosa is remarkably well sheltered from wind in the winter will be found to be correct, and as far as I can judge from the position I believe that Arosa will be found more favourably situated than any of the mountain resorts which have yet been tried in winter.

St. Moritz, October, 1882.

*Each of the mountain health resorts ought, in my opinion, to be separately and thoroughly studied, as I believe that in time we shall see that there are marked differences, and one is suitable for one class of patients while another may be more suitable for others, and we shall then see that the general classification of mountain health resorts is to be placed on a level with the remarks of a well-known German doctor, whose works on climatic questions are often quoted, who makes a comparison of a German watering place with Margate, Brighton, and Torquay, as if all places on the South Coast had a similar climate.

Ordinary Meeting, October 31st, 1882.

H. E. Roscoe, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

"Belted Skew Pulleys," by Archibald Sandeman, M.A.

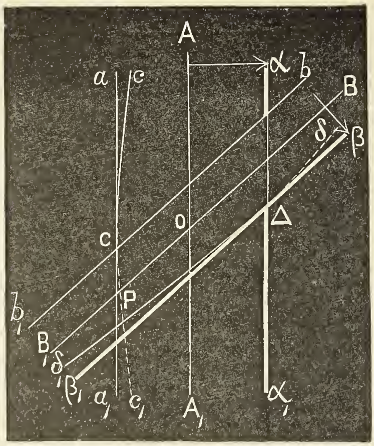
With that plane at right angles to the axis of a pulley which halves the face named THE PLANE OF THE PULLEY, and with the locus of the centre of the cross section of a belt named THE MIDLINE OF THE BELT; the only thing needed for either of two pulleys to drive the other by means of a closed belt looping them in tightly together (art. 184 of *Willis's Mechanism*) is

That the Midline of the belt leave each pulley in the plane of the other.

The planes of the pulleys may be taken vertical and therefore the axes horizontal. By so doing the belt is not drawn away by its own weight, and the axes are the more easily set up and steadied.

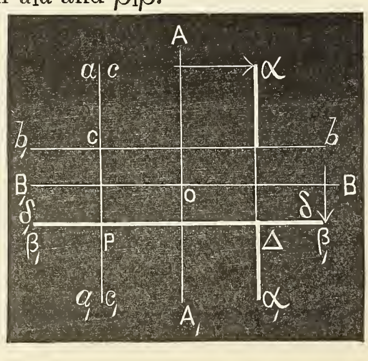
If the axes be parallel to one another the planes of the pulleys must be one and the same. Else the belt's midline would leave either pulley, not in, but on one side of, the other, and therefore run off this other toward that side. Thus with condirectionate or contradirectionate axes the midline of the belt lies wholly in the one plane of the pulleys. This is the simplest and commonest case of a pair of pulleys with open or crossed belt.

Call two straight lines SKEW when they are not in one plane. And call two pulleys SKEW when their axes are skew.



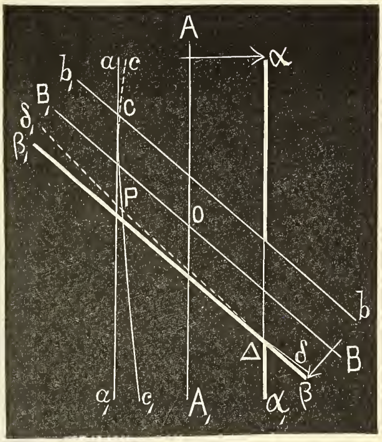
In a projection right down on a horizontal plane let A_1OA be the lower and B_1OB the higher of two given horizontal skew axes about which two pulleys of given diameters are severally to turn in such a way that, looking along A_1OA in the direction from A_1 to A and along B_1OB in the direction from B_1 to B, the rising points are to be on the left hand of the vertical plane through the axis and the falling points on the right.

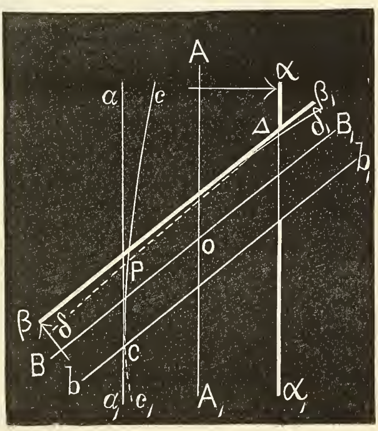
To A_1OA as axis fit a round roller or shaft or drum $A_1a_1aA\alpha\alpha_1A_1$, of the same circular cross section everywhere throughout as the pulley which is to turn about A_1OA, and so that a_1a and $\alpha_1\alpha$ may be severally the straight lines in which a horizontal plane through A_1OA cuts the drum face to left and to right. Also to B_1OB as axis fit a drum $B_1b_1bB\beta\beta_1B_1$, of the same circular cross section as the pulley which is to turn about B_1OB, and so that b_1b and $\beta_1\beta$ may be severally the straight lines in which a horizontal plane through B_1OB cuts the face of $B_1b_1bB\beta\beta_1B_1$ to left and to right. Moreover let C and Δ be the common sections severally of the vertical planes through a_1a and b_1b and of the vertical planes through $\alpha_1\alpha$ and $\beta_1\beta$.



If now the drums were to turn round in the same manners severally as the pulleys which are to have the severally same axes and cross sections; though all points in the drum faces would move in their own and several circles at one common speed, yet such only of them as lie in the straight lines a_1a and b_1b would at any instant be moving vertically upward and such only as lie in $\alpha_1\alpha$ and $\beta_1\beta$ vertically downward, and of these again only the two that lie in C would be moving vertically upward in one straight line and only the two that lie in Δ vertically downward in another.

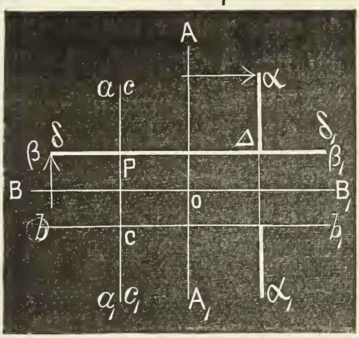
Lay a straight edge in and along the straight line C. Shift this straight edge both backward and forward so as never to be taken off either drum and so as always to touch each of the drum faces and be at right angles to the higher axis. Let c_1Cc be the line marked out by the points where the lower drum face is touched, and of this line let Cc_1 be the portion which lies on the same side of the plane through C perpendicular to the lower axis as Ca_1 and therefore Cc the portion which lies on the same side as Ca. If then through any point X in c_1Cc two planes be drawn perpendicular to the axes, and therefore cutting one another in a vertical straight line and the drums in a lower and a higher vertical circle, the straight edge when it passes through X touches the higher circle in some point Y; and a string may be stretched, first under the lower drum a_1a along



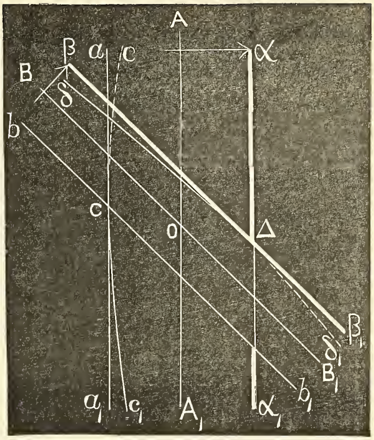


the lower circle toward and as far as X, next up along the line of the straight edge as far as Y, and lastly right on to and over the higher drum $\beta_1 b$ along the higher circle. This string too, if only guided on to the lower drum $a_1 a$ along the lower circle and pulled off from the higher drum $\beta_1 b$ along the higher circle, may be kept always unwinding itself off from the lower drum at X and always winding itself on to the higher drum at Y_1.

In like manner lay a straight edge in and along the straight line Δ, and shift this straight edge aside both ways so as never to be taken off either of the drums and so as always to touch each of the drum faces and be at right angles to the lower axis. Let $\delta_1 \Delta \delta$ be the locus of the point where the straight edge touches the higher drum face, and let $\Delta\delta_1$ be the portion on the same side of the plane through Δ perpendicular to the higher axis as $\Delta\beta_1$ and therefore $\Delta\delta$ the portion on the same side as $\Delta\beta$. If then through any point Y in the line $\delta_1 \Delta \delta$ two planes be drawn perpendicular to the axes, and therefore cutting one another in a vertical straight line and the drum faces in a higher and a lower vertical circle, the straight edge when passing through Y touches the



lower circle in some point X_1, and a string may be stretched over the higher drum $\beta_1 b$ along the higher circle toward and as far as Y, down along the straight edge line as far as X_1, and right on to and under the lower drum $a_1 a$ along the lower circle. And this string, if guided on to the higher drum $\beta_1 b$ along the higher circle and pulled off from the lower drum $a_1 a$ along the lower circle, may be kept always winding off the higher drum at Y and always winding on the lower drum at X_1.



Thus the vertical cross planes through X fix the circles for winding off from a_1a at X and on to $\beta_1 b$ at Y, and the vertical cross planes through Y fix the circles for winding off from the $\beta_1 b$ at Y and on to $a_1 a$ at X_1. Still the windings off at X and on at Y_1 cannot be windings of the same stretched string as the windings off at Y and on at X_1, unless X lie in the same circle as X_1 and Y in the same circle as Y_1; since by the bare turning of a drum a stretched string can only be guided from point to point in the same circle. That the same stretched string therefore may so engirdle the drums as always to wind itself off at the same fixed points X and Y and always to wind itself on at the same fixed points X_1 and Y_1 it is needful and it is enough that the vertical cross planes through X be the same as the vertical cross planes through Y. And this again happens just when the pairs of cross planes have the very same common section, or again just when the points X and Y lie in the same vertical straight line.

Hence through the lines c_1Cc and $\delta_1\Delta\delta$ draw vertical cylindric surfaces. Let P be the common section of these surfaces. Then planes drawn through the vertical straight line P perpendicular to the axes A_1OA and B_1OB are the planes of the pulleys.

If the axis be at right angles to one another (or rather, if from the forelook OA of the lower axis the forelook OB of the higher axis have a bearing with a right-hand-ward start either of once or of thrice a right angle), the lines c_1Cc and $\delta_1\Delta\delta$ are severally the straight lines a_1a and $\beta_1\beta$.

The cylindric surfaces are then nothing but the vertical planes through $\alpha_1\alpha$ and $\beta_1\beta$ and therefore cut one another at right angles in the straight line P. Then too the vertical plane through $\alpha_1\alpha$ not only touches the lower drum face but, passing through P perpendicularly to the higher axis, is itself the plane of the higher pulley; likewise the vertical plane through $\beta_1\beta$ not only touches the higher drum face but, passing through P perpendicularly to the lower axis, is the plane of the lower pulley. So then the vertical straight line P touches each of the faces of the pulleys and each of the midcircles. And so the millwright rule here holds good—" Plumb the centres of the leading off faces." These cases of rightangled axes are alone dealt with in art. 185 of *Willis's Mechanism,* and seemingly as if there were no others.

In all other cases the vertical cylindric surface through c_1Cc touches the vertical plane through a_1Ca along the vertical straight line C and in an unbroken sheet runs away endlessly therefrom on both sides between the parallel vertical planes through a_1Ca and A_1OA toward the vertical plane through A_1OA as an asymptote. Also the vertical cylindric surface through $\delta_1\Delta\delta$ touches the vertical plane through $\beta_1\Delta\beta$ along the vertical straight line Δ and in an unbroken sheet runs away endlessly therefrom on both sides between the parallel vertical planes through $\beta_1\Delta\beta$ and B_1OB toward the vertical plane through B_1OB as an asymptote. The plate bounded by the parallel vertical planes through a_1Ca and A_1OA is thus split by the vertical cylindric surface through c_1Cc into two slices having for a common bounding face the vertical cylindric surface through c_1Cc and for their other bounding faces severally the vertical planes through a_1Ca and A_1OA. And the plate bounded by the parallel vertical planes through $\beta_1\Delta\beta$ and B_1OB is split by the vertical cylindric surface through $\delta_1\Delta\delta$ into two slices having for a common boundary the vertical cylindric surface through $\delta_1\Delta\delta$ and for their other boundaries severally the vertical planes through $\beta_1 \triangle \beta$ and B_1OB. But as each of the bounding planes of each of these plates cuts or crosses each of the bounding planes of the other, so likewise must each of the plates themselves cross or cut through the other, so again therefore must each of the slices of either plate cut across each of the slices of the other, and so therefore lastly, must each of the cylindric surfaces cross or cut the other. Therefore the vertical cylindric surfaces through c_1Cc and $\delta_1 \triangle \delta$ cut one another in some vertical straight line P lying within the vertical prismatic rod which is common to the plates bounded severally by the parallel vertical planes through a_1Ca and A_1OA and by the parallel vertical planes through $\beta_1 \triangle \beta$ and B_1OB.

"Note on the Dimensions of Ships," by J. P. Joule, D.C.L., LL.D., F.R.S.

I have often thought that in practising the art of ship-building men have too much neglected the study of the forms of the fish which make the waters their permanent habitation and are designed for the most part to attain the highest degree of velocity in the pursuit of their prey.

No doubt the case of a ship partly, and that of a fish wholly immersed, are not strictly parallel, but they offer very many points for comparison of which we may avail ourselves.

A fish makes use of its tail fin as the chief and nearly sole instrument of propulsion, and in the adoption of the screw propeller in preference to the old side wheels the steamers of the present day have secured a great advantage over the old forms. In the proportion of length to those of breadth and depth, however, although there has of late been some improvement, there would appear to be a lingering tendency to hold by the old mistaken idea that a ship was rather to be regarded as a wedge to cut the water than as occupying the space of a wave of displacement, and so we have ships 9, 10, or even 11 times as long as broad and twenty times the length that they have draught. Now knowing as we do the magnitude of the skin resistance in ships and its smallness in the oily coats of fishes, one would expect that the length of the latter would be greater proportionally than that of the former, if ships were built in the proper form to secure a high velocity. But what is the fact?—On an average of sixteen fresh water fish delineated in Daniell I find that the extreme length inclusive of the tail fin is 4·22 times that of the extreme depth exclusive of the dorsal and ventral fins. The average breadth will be perhaps $\frac{1}{2}$ of the depth, making the proportion to length about 1 : 8.

On an average of three species of Whale, the Narwal, Greenland Shark, Dolphin, and the Porpoise, I find from Scoresby and other authorities the proportion of either depth or breadth to length, to be about 1 to 4·7, they having nearly circular sections. Therefore it appears that while in ships the proportion of length to width of midship immersion is in ships as 5 : 1, that of the shark, the porpoise, or dolphin, is not more than $1\frac{1}{2}$: 1.

Dr. Scoresby, in his 'Arctic Regions,' gives twelve miles per hour as the utmost speed of the Whale. But Mr. Baxendell gives it a velocity approaching 20 miles. I had an opportunity of witnessing the wonderful swimming powers of the porpoise during a voyage to the Clyde in the 'Owl' steamer on the 29th June last. About 8 a.m., the sea being calm near the Mull of Galloway, we were beset by a shoal of these animals which raced with the ship and kept along side for 3 or 4 minutes with the greatest ease. They swam in twos and threes at a foot or two distant from one another, several approaching within ten feet of the vessel, which was steaming at the rate of 13·4 statute miles per hour. If such a velocity can be maintained by the porpoise with its comparatively bluff figure head we may surely expect a much higher velocity in the case of fish more obviously designed for speed.

My son tells me that in a voyage of the 'Malvina' from Leith to London he had observed at night two fishes of about a yard long, which kept for a considerable time in advance of the cutwater of the ship, being visible by their phosphorescent light. The ship was at the time steaming at the rate of 15·2 statute miles per hour.

The investigation of the resistance of solids moving in fluids has been taken up theoretically by Thomson, Stokes, Rankine, and practically by Froude, who has found that the surface friction in long iron ships is more than 58 per cent of the whole. Froude recognized the study of the forms of animal life in guiding us to practical conclusions.

From the above considerations I am inclined to believe that a length of not more than five to one of breadth would be better than the extreme proportions of ships now in vogue, and that the greatest breadth should be considerably in advance of the midship.

"On the Coffee Leaf Disease of Ceylon, illustrated by preparations for examination under the microscope," by H. Marshall Ward, B.A., Fellow of Owens College. Communicated by Prof. Osborne Reynolds, F.R.S.

Mr. Ward commenced by sketching shortly the history of the coffee leaf disease, from its discovery in Ceylon, in 1869, to the present time, and gave some figures showing its effect on the exports of coffee. He then proceeded to describe the symptoms by which the disease is recognised.

The normally dark-green, laurel-like coffee leaves become spotted with yellow blotches, which arise as pale, minute spots on the under side, soon spreading in a centrifugal manner, and showing through above. Each spot becomes darker with age, and multitudes of minute yellow *spores* make their appearance on the under side of the leaf, forming a powder—the so called "rust"—on the outer surface of the spot. Coloured drawings of coffee leaves thus affected with "disease-spots" were handed round for inspection.

As the number of yellow spots increase, the leaf loses its bright green colour, turns yellow, and drops off. As large numbers of leaves thus prematurely fall from the branches, the latter become shrivelled and brown, and the fruit drops in all stages.

The lecturer then proceeded to describe the microscopic details of what is seen inside a healthy leaf, and compared it with what is found inside the yellow "disease spots." The passages between the green cells of the leaf are found to be blocked up by a fungus *mycelium*, consisting of short, much-branched tubes, which send off curious sucking organs into the cells.

As the fungus grows older, and the yellow spots, which are the external evidence of its presence, become larger, it is discovered that the contents of the green cells become sucked out into the fungus. A section showing the *mycelium* and its minute sucking organs was shown under the microscope.

When a section is taken through a more advanced spot, on which the yellow "rust" has formed, the origin of the latter is seen to be as follows: certain branches of the fungus grow together through the *stomata* of the leaf, and bud off thousands of *spores*. These numerous spores form the yellow powder or rust. An instructive section of this kind, in which the mycelium and spores were stained blue, was shown afterwards under the microscope.

On one spot as many as 100,000 or more of such spores have been estimated, and 127 such spots were counted on one pair of leaves. They are detached with the slightest shake.

Mr. Ward then described the germination of the spore. On glass or inorganic bodies the spore, after a few hours in water, throws out a tube, which reaches a certain stage in 24—48 hours, and then dies. In nutritive fluids of various kinds, also, or on the upper side of the leaf, stem, &c., no further development was possible. On germinating the spore in drops of water on the *under* side of the leaf, however, the germinal tube soon enters a *stoma*, and at once commences to form the *mycelium* inside the leaf. This grows, feeds on the cell contents, blocks up the passages, &c., and causes the development of a yellow "disease spot," such as those described.

Experiments were made which showed that the yellow disease spot only appears where such a tube has entered the leaf, and nowhere else on the leaf or plant, and that leaves or plants on which no *spores* were sown—and therefore no tubes entered—formed no spots. Shelter from spores is a certain guard against disease.

It was found, as a mean of very many experiments, that the yellow disease spot appears about 14 days after the sowing and germination of the spore on the leaf, and that the spores constituting the "rust" of such a spot commenced to form during the third week after the sowing.

The yellow disease spot, therefore, is the outward appearance produced by the fungus mycelium occupying the space in the leaf. This mycelium blocks up the passages, robs the cells of food substances which should have gone down to the branches, fruit, &c., interferes with normal respiration and other processes, and thus shortens the life of the leaf. Since the tree thus derives so little benefit from its leaves, it cannot bear so much fruit.

Further experiments proved that the age and condition of the leaf, the kind of coffee, &c., have no effect on the problem of its infection; all can be infected, though thick leaves can support more mycelium than thin and succulent ones.

Mr. Ward then proceeded to show how these results of experiments and observations in the laboratory were applied to explain the course of events on coffee estates.

Observations demonstrated that spores are blown about estates, reach the leaves of the coffee, are washed to the edges and lower sides, and there germinate; that, therefore, all the conditions of the artificial infection are brought about in nature. Having learnt particulars as to the periods of growth of coffee, the time occupied in infection, experiments, &c., the next step was to ascertain how far the changes in climate, &c., account for the rise and fall in the "virulence of the disease"—*i.e.* in the quantity of leaf-destroying fungus present at any time.

On one of a number of leaves which were carefully watched during several months, the first spot became most evident in the beginning of June, and on June 3rd was throwing off spores. On June 29th there were 35 new spots forming spores, and on July 15th appeared 12 others. On July 23rd the leaf began to show signs of falling, and it dropped on the 26th. In such a case, the successive generations of mycelium appeared at such intervals as would be accounted for if they arose from spores derived from the first spot. No doubt the spores were shaken around, and germinated soon after, each becoming the centre of a new spot as described.

In a given district the weather was dry and hot during the early period of the year, and from January to March there were few leaves on the trees, and little or no moisture to bring about the germination of any stray spores on them. In April and May the wet growing season commences, many new leaves are formed, and the few spores present germinate, and produce disease spots in two or three weeks after; hence, by June, there are several "disease spots," each of which is shedding spores all around at every shake. These spores, scattered on the leaves, germinate in the rains which still continue, and thus, by July or thereabouts—the process having gone on normally—a larger outbreak of the "disease spot" occurs from the numerous new centres. During July and August very many leaves fall, and a lull occurs until the renewal of the growing period in September and October produces more leaves. These, meanwhile, are having spores scattered on their surfaces, accumulation of disease spots continues through the next three or four weeks, and in December, or thereabouts, the second general "attack of disease" has become established.

Very numerous and important experiments, published in detail in the "Journal of the Linnæan Society," Bot., Vol. xix., August, 1882, could only be shortly adverted to, and the author expressed his conviction that so bare an outline of the results as the short time at his disposal allowed, would not convey sufficiently clear ideas of the matter; and, indeed, to an audience unacquainted with the details of growth, cultivation, &c., of coffee, and the conditions of existence in a tropical island, it was not easy to give an intelligent sketch in a short time, even of the salient points.

As to remedial measures, Mr. Ward expressed his satisfaction with the energetic efforts of the Ceylon planters, who fully recognise the importance of planting tea, cinchona, cocoa, "India-rubber," and other trees which no such disease attacks, and which, of course, screen the coffee more or less—an obvious mode of lessening the areas of coffee exposed to the wind blown spores of *Hemileia*, and of adding new sources of income.

The following paper was read at the Ordinary Meeting held on the 17th October, 1882.

"Note on the Development of Living Germs in Water," by Dr. R. Angus Smith, F.R.S.

In a report on Proceedings under the Rivers Pollution

Prevention Act, I mention my wish to develop germs of living things in water as a test for purity. The quotation is from a paper printed by this Society in 1867. The results were correct and useful, but not striking enough to attract much attention, although I think chemists have not been sufficiently active in using the microscope. Having long seen its importance, I confess to having done too little with it. In a report under the Alkali Act during the year 1873 I mention a second attempt to render the existence of organic matter more perceptible by using the air washings to act upon sugar, and after many trials I was disappointed; still I came to the conclusion "that the air of a town influences fermentation to a certain extent."—10th Report, p. 43.

I neglected this development also too much, but Dr. Koch, of Berlin, has shown us how to preserve the indications of organic vitality by the use of gelatine. I believe he was the first to use it. It is from Dr. Koch, at any rate, that I learned the use of gelatine. About 2½ per cent of gelatine well heated in a little water is mixed with the water to be tested, and the mixture forms a transparent mass which is not movable like the water itself. When soluble or unobserved matter develops from the organic matter of the waters and makes itself visible in a solid and insoluble form, it does not fall to the bottom, but each active point shows around it the sphere of its activity, and that sphere is observed and remains long. The gelatine preserves to us the whole action, so far as the more striking results are concerned, and keeps a record, for a time, both of the quality and intensity of life in the liquid. I speak at present of the more striking effects, which are clear and abundant, every little centre of life making itself clear to the eye and sometimes expanding its influence to reach both sides of the tube. It seems to me now essential that all chemical examinations of water should be supplemented by an enquiry, like this of Dr. Koch's, into the comparative activity of the living organisms. How far this may go it would be absurd to attempt to say, and I never have much hope of a man who writes about the future of truth; he evidently attempts too much. I am satisfied to bring forward such facts as I know in the present, so that chemists may not be too late in attending to the new ideas.

The water must not have too much gelatine in it, if so the action is stopped. It must not have too little, if so the gelatine becomes liquid too soon and the action of the individual centres is not observed. When a centre acts it makes around it a sphere in some waters, and the sphere which has the appearance of a thin vesicle is filled with liquid. These spheres form in a day or two according to the water, and at the bottom is a white mass containing active bacteria chiefly. The liquid filling the spheres may be taken out by a pipette and examined, as also the bacteria which lie at the bottom.

I have not examined a sufficient number of waters to give general rules, but I hope to do so. It is an investigation which would properly belong to Professor Koch, and I should not have touched it had I not found that it brought into use my own enquiries as to fermentation, which were earlier, but may now be considered only a supplement to Dr. Koch's. This is by the use of sugar in addition to the gelatine. By this means a very great amount of gas is developed and retained in the gelatine. The striking amount of spheres and gas bubbles render the examination of water by this method less dependent on the opinion of the operator, and a photograph may be taken of each specimen and the result preserved as evidence.

At the same time I know that it is necessary to examine waters of various kinds before we make or find rules, and this slight account is a mere beginning. I have as yet examined no chalk water for example, but have been confined chiefly to the Manchester district, hill water, impure brook and pond water, Mersey, Irwell, and Medlock water, and canal water. In certain specimens of Manchester supply the spheres appear on some days very few, on other days the amount is enormous and heavy, the whole of the tube in which the experiment is made is filled with spheres. At such times the water is highly impure and complained of by the public. We have a very easy proof therefore of the value of this test.

The photograph would be a visible report made by nature when the water has active organisms in it. The globules do not show themselves in strong sewer water, but the whole mass becomes turbid and the surface of the gelatine becomes liquid and full of life. This liquid condition gradually increases until the whole is reached. We have therefore two striking conditions well marked out.

A third may be said to exist, but it is often a mere beginning of the globules. This is shown by the formation of a small white opaque point. If this point is examined it is seen to be full of life like the lower part of the spheres and the fluid portion of the gelatine when this fluidity begins on the surface.

I find, also, that the solidity or fluidity of the gelatine is an important indication. This is known by the depth to which a certain weight will sink in it.

I use the word bacteria at present because, although I have observed various forms, I do not intend to investigate the separate functions of each.

At present this mode of examining water seems to me to be far more important than the chemical, more decided and telling, but we cannot neglect the chemical.

An account of a few specimens is given here.

Specimen 1.—25 cc. gelatine solution $= 2\frac{1}{2}$ p.c. solid $+$ 25 cc. distilled water $+$ 5 mgms. sodium phosphate.

After 2 days a few white spots appeared.

After 3 days 3 or 4 small spheres appeared, containing living bacteria.

After 4 days spheres enlarged and a deposit forming at the bottom of them very full of bacteria.

After 6 days the surface of the jelly was beginning to give way.

After 8 days the surface layer was liquid to the depth of a millimetre, but the rest of the gelatine was still firm, with no smell; liquid layer alkaline.

Specimen 2.—25 cc. gelatine + 25 cc. Manchester water + 5 mgms. sodium phosphate.

After 1 day the tube contained a few minute specks.

After 2 days a number of minute spheres, not to be counted, appeared, and a turbid band was formed near the surface of the jelly, which was very rich in living bacteria.

After 3 days spheres became larger and the whole of the gelatine was softened; a number of air bubbles appeared also.

After 4 days air spheres had risen to surface, bacteria spheres disappeared, leaving the liquid jelly turbid and smelling offensively; liquid alkaline.

Specimen 3.—25 cc. gelatine + 25 cc. Manchester water + 5 mgms. sodium phosphate after filtration through spongy iron.

The result here resembled that of the distilled water.

25 cc. gelatine + 25 cc. Mersey water at Northenden + 5 mgms. sodium phosphate.

After 1 day a turbid band appeared near the surface and a number of minute spots appeared.

After 2 days these spots had spheres about them.

After 3 days the surface layer was quite liquid and turbid and a number of discs of gas appeared. Bacteria in spots and surface liquid.

After 4 days in a somewhat similar condition, but the surface liquid possessed a very disagreable smell.

Specimen 4.—25 cc. gelatine + 25 cc. Bridgewater canal water + 5 mgms. sodium phosphate.

After 2 days a number of spots appeared dispersed throughout the tube.

After 3 days the tube contained one mass of small spheres and spots.

After 4 days a number of discs of gas appeared, the surface layer was becoming liquid,

Specimen 5.—25 cc. gelatine + 25 cc. Birch pond water + 5 mgms. sodium phosphate.

After 1 day no alteration.

After 2 days a few specks appeared dispersed throughout the jelly.

After 3 days a number of spots appeared and discs of gas, surface layer of jelly becoming liquid.

A disc of gas is formed when the gelatine remains firm and the gas struggles for freedom.

Specimen 6.—25 cc. gelatine + 25 cc. Carlile's pond water, near Alexandra Park + 5 mgms. sodium phosphate.

After 1 day specks appeared dispersed throughout the gelatine.

After 2 days numberless very minute spheres appeared.

After 4 days the spheres had increased in size.

After 7 days a number of spheres of gas appeared.

Specimen 7.—25 cc. gelatine + 25 cc. ditch water, near Alexandra Park + 5 mgms. sodium phosphate.

After 1 day a number of specks appeared throughout the jelly.

After 2 days numberless spheres appeared.

After 3 days the surface of the jelly had become liquid and turbid, the spheres were increasing in number.

After 7 days a number of spheres of gas appeared and the whole mass was becoming liquid.

Specimen 8.—25 cc. gelatine + 25 cc. N. Berwick water supply + 5 mgms. sodium phosphate.

After 1 day the tube seemed one mass of minute specks.

After 2 days a number of minute spheres appeared and a turbid band appeared near the surface of the gelatine.

After 3 days spheres had increased in size, a number of discs of gas appeared.

After 4 days the spheres were disappearing, the surface of the jelly was becoming liquid (these spheres did not leave. a deposit).

After 8 days the surface layer was quite liquid but the rest of the jelly was firm, and there were still left a number of discs of gas and a number of minute spots, smell offensive

Specimen 9.—25 cc. gelatine + 25 cc. Stockport water supply + 5 mgms. sodium phosphate.

After 1 day a number of minute specks appeared and a few small discs of gas.

After 2 days these discs of gas were getting larger, and on the third day the tube was one mass of discs of gas.

After 5 days the jelly was liquid and the discs of gas rose to the surface when shaken, smell disagreeable.

Specimen 10.—25 cc. gelatine + 25 cc. Medlock water + 5 mgms. sodium phosphate.

After 1 day a number of spots appeared dispersed throughout the jelly.

After 2 days these spots were more decided and a distinct turbid band appeared at the surface of the jelly.

After 3 days a number of flattened discs of gas appeared, surface layer semi-liquid and turbid.

Specimen 11.—25 cc. gelatine + 1 cc. hay infusion + 24 cc. distilled water + 5 mgms. sodium phosphate.

After 1 day the surface layer of the jelly was altering, the layer was becoming turbid and liquid.

After 2 days the alteration was still more advanced, but the surface layer was not yet liquid.

After 3 days the surface layer was liquid.

After 7 days a great deal of the jelly had become liquid, and white specks appeared dispersed throughout the jelly.

Specimen 12.—5 cc. gelatine + 1 cc. putrid urine + 24 cc. distilled water + 5 mgms. sodium phosphate.

After 1 day the surface layer was becoming turbid and liquid.

After 2 days the alteration more advanced, surface of jelly semi-liquid.

After 3 days the jelly at the surface was quite liquid, turbid, and offensive.

This subject is being more fully developed under Dr. Koch by Dr. Rozahegyi, and chemists must prepare for a new condition of things.

MICROSCOPICAL AND NATURAL HISTORY SECTION.

Ordinary Meeting, 9th October, 1882.

James Cosmo Melvill, M.A., F.L.S., President of the Section, in the Chair.

Dr. Hartog called the attention of members to the fauna, especially rich in special forms of Cladocera, found at or near the surface of deep freshwater lakes. He urged members to use the tow net whenever they had the opportunity on calm, fine afternoons, even at this time of year.

Professor W. C. Williamson, F.R.S., made a communication respecting and exhibited a series of preparations from the coal measures, illustrating the present state of our knowledge of the relations between Lepidodendron, Sigillaria, and Stigmaria.

Commencing with a statement of Brogniart's dictum, that Lepidodendron was a cryptogam and Sigillaria a gymnosperm, and showing by a sketch the appearance which led Brogniart to found his distinction between them, viz., the appearance in the latter of an exogenous vascular zone externally to the non-exogenous vascular cylinder which he found in the former genus, Professor Williamson proceeded to show that the presence and size of the ring of exogenous growth in the stem was merely a question of the age of the plant examined. Further, that the markings on the outside of the stem, supposed to be diagonal in Lepidodendron and vertical in Sigillaria, probably depended upon differences which were not even generic, but which might have occurred in the same plant in different stages of growth, the Lepidodendroid condition being the younger one.

Turning to Stigmaria, Professor Williamson showed that they possessed two striking peculiarities—1st, they branched and subbranched dichotomously. Such branches, however, had no share in the work of absorbing nutriment from the soil. This function was performed by large but delicate rootlets given off abundantly from the surface of each root branch. 2ndly, these rootlets possessed a single bundle of small vessels running longitudinally through the cortical investment. In each rootlet this vascular bundle commenced its growth as a single vessel, developed eccentrically within an innermost cylinder of cortical cells, and additional vessels were added to the bundle centripetally as the rootlet advanced in age and size until it developed into an eccentric cluster of 40 or 50 vessels.

This peculiar arrangement is only found amongst living plants in the Ophioglossums and Lycopods, in the latter of which alone does the dichotomous branching of the roots occur. It would appear, therefore, that the two features, viz. the peculiar growth and structure of the rootlet and the dichotomous ramification of the roots seen in the fossil types, have been concentrated in these degraded living representatives in the one root organ. Anyhow the facts afford a strong confirmation of the Lycopodiaceous character of the fossil Sigillaria to which these Stigmarian roots in part belonged.

Referring to Haloma, which Binney thought was a root of Lepidodendron, Professor Williamson exhibited a cast of a fine specimen of Lepidodendron elegans from the Leeds Museum, in which each Lepidodendroid branch terminated dichotomously in a series of subdivisions, each one of which possessed all the characteristics of a true Haloma.

Dr. Hartog, referring to the memoir recently published by Profesor Williamson and himself in the *Annales des Sciences Naturelles,* in which they criticised the opinions of M. Renault on the relations of Lepidodendron, Stigmaria, and Sigillaria, spoke of the part he had taken in the matter. He also made some remarks on Professor Williamson's interpretation of his discoveries in connection with Stigmaria.

General Meeting, November 14th, 1882.

Edward Schunck, Ph.D., F.R.S., &c., Vice-President, in the Chair.

The Rev. Brooke Herford, of Boston, U.S., was elected a Corresponding Member of the Society; and Mr. Harry Marshall Ward, B.A., Berkeley Fellow, Owens College, was elected an Ordinary Member.

Ordinary Meeting, November 14th, 1882.

Edward Schunck, Ph.D., F.R.S., &c., Vice-President, in the Chair.

"On Singular Solutions of Differential Equations," by Robert Rawson, Esq., Hon. Member, Assoc. I.N.A., Mem. of the London Math. Society.

The principle employed in this paper is to impress such forms upon the complete primitive of a differential equation as will lead at once to its singular solution.

By this method the two theorems which produce singular solutions, viz.., condition of equal roots of the c- equation and of the p- equation are readily derived.

The properties also of $\frac{dy}{de}=0$, $\frac{dx}{de}=0$, $\frac{dp}{dy}=$ infinity, and $\frac{d}{dx}\left(\frac{1}{p}\right)=$ infinity, with their limitations are shown to be consequences of this principle.

Remarks occur on the valuable papers of Sir James Cockle, Professor Cayley, Mr. Glaisher, and Boole's proof of Euler's theorem to determine whether a solution of a differential equation is singular or particular, and an attempt is made to solve this problem without using a troublesome transformation as has been done by Boole and others.

Ordinary Meeting, November 28th, 1882.

J. P. JOULE, D.C.L., LL.D., F.R.S., &c., Vice-President, in the Chair.

"On the Transformation of a Logical Proposition containing a Single Relative Term," by JOSEPH JOHN MURPHY, F.G.S. Communicated by the Rev. ROBERT HARLEY, F.R.S.

Abstract.

In the system here proposed, R means any relation whatever, and R^{-1} the inverse relation. The equation

$$X = RY$$

and its inverse

$$Y = R^{-1}X$$

mean respectively that X is teacher of Y and Y is pupil of X, without implying whether or not X has any other pupils and Y any other teachers.

$$X = 1RY$$

and its inverse

$$Y = 1^{-1}R^{-1}X$$

mean respectively that X is the only teacher of Y, and Y the pupil of none but X.

If X and Y are the names of classes instead of individuals,

$$1X < RY$$

means that every X is teacher of a Y: and its converse

$$R^{-1}1X < Y$$

means that pupils of every X are included in the class Y The proposition

$$1X < R1Y$$

means that every X is teacher of every Y. This is a doubly total proposition (the preceding one is singly total), and such a proposition is inevitable, giving

$$1\mathrm{Y} < R^{-1}1\mathrm{X}$$

A singly total proposition of the above form admits of the following four equivalent forms, whereof the truth or falsehood of each implies the truth or falsehood of all—$\bar{\mathrm{V}}$ signifying not = teacher, and $\bar{\mathrm{X}}$ and $\bar{\mathrm{Y}}$ not = X and not = Y :—

$$\begin{array}{l} 1\mathrm{X} < R\mathrm{Y} \\ 1\bar{V}^{-1}1\mathrm{Y} < \bar{\mathrm{X}} \\ R^{-1}1\mathrm{X} < \mathrm{Y} \\ \mathrm{X}\bar{V}1\mathrm{Y} < 0 \end{array}$$

A doubly total proposition of the above form has four pairs of equivalent forms, as follows :—

$$\begin{array}{ll} 1\mathrm{X} < R1\mathrm{Y} & 1\mathrm{Y} < R^{-1}1\mathrm{X} \\ 1\bar{V}\mathrm{Y} < \bar{X} & 1\bar{V}^{-1}\mathrm{X} < \bar{\mathrm{Y}} \\ 1\mathrm{Y} < 1^{-1}\bar{V}^{-1}\bar{\mathrm{X}} & 1\mathrm{X} < 1^{-1}\bar{V}\bar{\mathrm{Y}} \\ \mathrm{X}\bar{V}\mathrm{Y} < 0 & \mathrm{Y}\bar{V}^{-1}\mathrm{X} < 0 \end{array}$$

The concluding part of the paper treats of the application of these principles to transitive relations, *e.g.* the relation of ancestor and descendant, where the ancestor of an ancestor is an ancestor.

Joint Ordinary Meeting of the Society, and the Microscopical and Natural History Section of the Society,
December 12th, 1882.

H. E. Roscoe, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

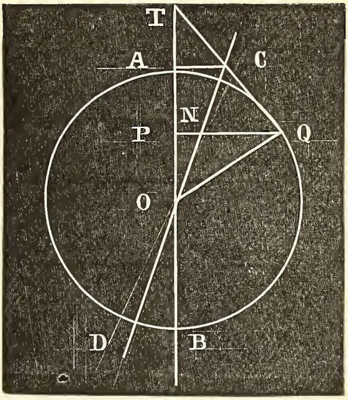
Mr. James Heelis made some remarks upon the causes of the movement of the old Rhone Glacier with special reference to the power of gravity to produce such movement when considered in connection with the gradient down which the glacier has passed.

"On an Elementary Solution of the Dynamical Problem of Isochronous Vibration," by Professor OSBORNE REYNOLDS, M.A., F.R.S.

When a heavy body is free to move in one direction, subject only to a force which is proportional to the distance the body has moved from some neutral position and tends to return the body to that position, the body will, if set in motion, vibrate about the neutral position in a period which is independent of the magnitude of the motion.

The deduction of this theorem from the laws of motion, although well known, is generally accomplished by the solution of a differential equation. In some text books this is avoided by comparing the law of force on the vibrating body with that of a component of the centrifugal force on a revolving body; this method involves no mathematical difficulties, but it is indirect and hides rather than removes the dynamical difficulties. My own experience has shown me that the mathematical difficulty or obscurity of these methods stand very much in the way of those who are commencing the study of practical mechanics, in which vibration and oscillation play a part of fundamental importance. It was with a view of meeting the requirements of such students that I sought for a method involving only Elementary Mathematics, in which the solution depended directly on the principle of the conservation of energy. Having succeeded in finding such a method which, although it bears a superficial resemblance to the method of the text books already mentioned, so far as I am aware, has not hitherto been published, it seems that it may be useful to publish it.

The method is to show that the vibrating body will at all times be opposite, in a direction perpendicular to its path, to a body revolving uniformly in a circle, having a diameter equal to the amplitude of oscillation, with a velocity equal to the greatest velocity of the vibrating body.



Let O be the neutral position of the body considered as a point, AOB the path described during oscillation, let p be the force on the body when at a unit distance from O, so that as the force varies uniformly with the distance, px will be the force at the distance $OP = x$.

Take PN perpendicular to OP and make PN on some scale equal px, then N will lie on a straight line COD, and the area OPN will represent the work U done against the force in moving from O to P and

$$U = \frac{PN \times OP}{2} = \frac{px^2}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Let W be the weight and v the velocity of the body, then by the conservation of energy

$$\frac{W}{2g}v^2 + U = \frac{Wv_0^2}{2g} = \epsilon \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where E is the energy of the system and v_0 the velocity at O, or substituting from equation (1)

$$\frac{Wv_0^2}{2g} = \frac{Wv^2}{2g} + \frac{px^2}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

but when P is at A or B $v = O$, put $OA = a$, then

$$pa^2 = \frac{Wv_0^2}{g} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

and equation (3) becomes

$$\frac{W}{g}v^2 = p(a^2 - x^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Describe a circle about O as centre with a radius a, and let PN produced meet this circle in Q, and let QT the tangent at Q meet AB in T, then the triangle QTP will be similar to QOP and

$$\frac{PT}{TQ} = \frac{PQ}{OQ} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Now suppose a point at Q moving with a velocity u such that it keeps opposite to P.

Then the component of this velocity parallel to AB is

$$u\frac{\text{PT}}{\text{TQ}}=u\frac{\text{PQ}}{\text{OQ}^2}$$

and this is v since Q remains opposite to P.

Therefore substituting in equation (5)

$$\frac{\text{W}}{g}u^2\frac{\text{PQ}^2}{\text{OQ}^2}=p(a^2-x^2)$$

Then since $\text{PQ}^2=\text{OQ}^2-\text{OP}^2=a^2-x^2$ we have

$$1pa^2=\frac{\text{W}}{g}u^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Therefore Q moved on the circle with a velocity

$$u=a\sqrt{\frac{gp}{\text{W}}}$$

which is constant. Or the motion of the vibrating body will be such that it always keeps opposite in a direction perpendicular to its path to a body revolving in a circle of diameter equal to the amplitude and with the greatest velocity of the vibrating body.

This completely defines the motion of the vibrating body for starting from A the arc described by the vibrating after time t is $\sqrt{\frac{pg}{\text{W}}}t$ and the vibrating body will be opposite.

The time of a complete oscillation will be the time taken to complete a revolution when

$$\sqrt{\frac{pg}{\text{W}}}t=2\pi.$$

Therefore the time of oscillation is given by

$$t=2\pi\sqrt{\frac{\text{W}}{pg}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

"On the occurrence of *Potamogeton Zizii*, M. and K., in Lancashire, and in Westmoreland," by CHARLES BAILEY, F.L.S.

About four years ago a new pond-weed was added to the British flora, by Mr. Andrew Brotherston, of Kelso, who found it growing in Cauldshiels Loch, near Melrose, Roxburghshire. Mertens and Koch had named the plant *Potamogeton Zizii* after its first discoverer, Dr. Ziz; its affinities are with *P. lucens*, *P. heterophyllus*, and their allies. Though a rare plant it has a somewhat wide distribution in Europe, extending from the Scandinavian provinces in the north to Bohemia and Bavaria in the south.

A description of the Cauldshiels plant, together with its synonymy and relationships, have been carefully worked out in a paper by Dr. Trimen in the 'Journal of Botany,' No. 202, October, 1879, illustrated by a plate.

The distribution in Britain, so far as it has been recorded, is somewhat restricted, as the published localities are in the counties of Roxburgh and Forfar, in Scotland, and of Anglesey, in Wales. So far, there have been no recorded occurrences of the plant in England or Ireland, but as it is liable to be passed over for *Potamogeton lucens*, it will doubtless be found to be pretty widely distributed in the British Isles; indeed Mr. Arthur Bennett has already had it sent him from several additional counties.

I have now to report its occurrence in two English counties, namely, Lancashire and Westmoreland, and specimens from both localities are being distributed, with the plants of the current year, to the members of the Botanical Exchange Club.

I first collected the plant on the 17th September, 1870, close to the western shore of Derwentwater, opposite Rose-trees, three quarters of a mile to the south of the little village of Portinscale. On that occasion there were neither flowers nor fruit, and I was unable to refer it to any of the recognized British forms. It remained in my herbarium for some years, when Mr. Arthur Bennett, F.L.S. (of Croydon), who has paid great attention to this group of plants, was good enough to examine all my British Potamogetons, and he also was doubtful as to the proper nomenclature of the Derwentwater specimens of 1870, thinking that it might be *P. Zizii*, although showing an approach to *P. decipiens* in the structure of its leaves.

The uncertainty about this plant, therefore, led me to make a careful search for fruiting specimens in Derwentwater, during a visit in September last. The station in which the plant was the most abundant in 1882, is in the easternmost of two small bays which lie to the east of the outflow of the lake. The plant grows with *Scirpus lacustris*, L., in about four to six feet of water, and there are several colonies of it. Out of some hundreds of plants examined in *situ* there were but two flowering specimens, one of which is now exhibited to the members, and the other was sent to Mr. Arthur Bennett, who pronounced it to be *P. Zizii*.

Later on, on the 22nd September, 1882, I found the same plant growing in the greatest profusion at the northern end of Coniston Lake, and flowering abundantly, nearly all the plants being in flower or fruit. I had no means of ascertaining the depth of the water, but in many places it would not be less than eight or ten feet; the longest specimen actually gathered was six feet long. I also saw the same species growing in Windermere, on the western side, near the new Ferry Hotel, but I could not collect it as I was on the steam ferry at the time.

According to the notes of Mr. Andrew Brotherston in the Reports of the 'Botanical Exchange Club' for 1879, and of the 'Botanical Record Club' for 1878, the plants from Cauldshiels Loch grew in water less than one foot deep in 1878, and two feet deep in 1879; Mr. Brotherston's specimens of each of these two years' growths, now exhibited for comparison, show considerable difference in habit; the 1878 plants possess short internodes, and subsessile leaves which are crowded on the stem and its branches. Those which were collected in the same station in the year following, in water two feet deep, have such long internodes and peduncles (the latter from seven to nine inches in length) and such distant leaves on the flowering branches, as to appear to belong to quite a different plant. These two states of the same plant seem to represent the two varieties figured by Reichenbach in his "Icones Floræ Germanicæ et Helveticæ," Vol. VII., tab. xxxviii. and xxxix., which are thus characterised:—

a. validus Fieber; stem robust; lower leaves subsessile; upper leaves shortly petiolate.

b. elongatus, M. K.; stem elongate; internodes, leaves, and peduncles prolonged.

The only Derwentwater flowering specimens I saw were very similar to the Cauldshiels Loch specimens of 1879, save that they were five feet long; while all the non-flowering specimens had short internodes in their upper portions. The Coniston plants on the contrary had very long internodes, while their peduncles (which were very brittle) measured from eight inches to a foot and a half in length; the stalk of the uppermost leaves measured from a quarter of an inch to an inch and a half. I have therefore referred them to the var. *elongatus* of Mertens and Koch, but Mr. Bennett considers that the Coniston plant is nearer to M. & K.'s typical plant than the Derwentwater plant, although neither is the type as found in Germany and Sweden; but more like the French plant from the Loire.

Potamogeton Zizii differs from *P. heterophyllus* in having no floating leaves, and in its submerged leaves not being so sessile or narrow; it differs from *P. lucens* in having its stipules keeled instead of winged; and from *P. nitens*, and *P. decipiens* in its much longer peduncles and in its leaves not being amplexical or rounded at the base. It should be looked for in the Cheshire and other meres in the neighbourhood of Manchester.

"On the Lincolnshire locality for *Selinum Carvifolia*, L.," by Charles Bailey, F.L.S.

Aided by detailed indications kindly given me by Dr. F. Arnold Lees, I paid a special visit on the 14th September, 1882, to the Lincolnshire station for the most recent addition to our flowering plants, viz., the *Selinum Carvifolia*, L., an umbelliferous plant discovered by the Rev. William Fowler, M.A., of Lincoln, and a member of the Botanical Record Club.

Its occurrence as a British plant was first announced on pp. 127, 128, and 156 to 161 of the 1880 Report of the Record Club, and its first announcement was a surprise to botanists, as it was scarcely credible that a plant of so conspicuous a stature as from one to four feet should have escaped the notice of so many critical eyes during the last two centuries, and it encourages the hope that there are other undetected native species awaiting the researches of British botanists.

The Lincolnshire locality is situate in a sparsely-populated portion of the county, in a somewhat woody, but very flat district with long straight roads and drains. It is nearly equidistant from Appleby, Scawby, and Glamford Briggs (Brigg), Scawby and Brigg forming the base of a triangle, of which the station for the *Selinum* is the apex. The locality may be readily identified on the Ordnance map from its contiguity to the old Ermine Street, which runs in a nearly straight north line for thirty miles from Lincoln to the Humber. The high road is left one mile north of the village of Broughton, through a gate which leads into a wood by a cart track, running due east, and opposite a lodge. In about a hundred yards or more the track opens into a narrow damp pasture which slopes towards a small brook flowing eastward.

The *Selinum* begins to occur, in plenty, in this pasture as soon as it is clear from the shade of the wood. Judging by the foliage of the plant it is scattered over the small area of the field, preferring its dampest portions. Very few examples of the plant were visible on the occasion of my visit, as the field had been recently mown, but I managed to procure a few plants at the edges of the brook, and in the shade of some trees. These plants were for the most part prostrate owing to a flood just subsiding, and as they lay tangled in the rank vegetation of the watercourse, their winged stems afforded a more ready means of identification by touch than anything which presented itself above the level of the water or amidst the prostrate vegetation of the banks. Notwithstanding the lateness of my visit, most of the examples were found in flower, only a small proportion possessing immature fruit.

So far as could be judged from the surroundings of the station as seen in a single flying visit, I should not hesitate to consider the plant as belonging to our indigenous vegetation, and I am quite of the opinion of Dr. Lees, given before it was discovered the following year in Cambridgeshire, that it will "be found to occur elsewhere in England, most likely in some other of the eastern counties." (Report, Botanical Record Club, 1880, p. 128). There does not seem to be any ground for considering it an alien, as it is difficult to assign a reasonable explanation for its introduction. Further, the distribution of the plant in all countries washed by the same seas which touch our eastern and south-eastern coasts, is another and a very strong indication of its English nativity.

Mr. JOHN BOYD exhibited a fine living specimen of *Argulus foliaceus*, a parasite of the Carp.

Mr. R. D. DARBISHIRE gave an account of dredging at Oban in September, in company with Dr. Marshall, Mr. Archer, and Mr. Walker, and exhibited and distributed specimens. Without reaching deeper water than 26 fathoms they had taken within a few miles of Oban a considerable variety of animals.

Sponges: of several genera.

Hydrozoa: 12 larger forms, including Antennularia ramosa and 2 varieties of A. antennina, and Aglaophenia pennatula.

Actinozoa: Adamsia palliata, large, and other forms. Funiculina quadrangularis and Pennatula phosphorea. Of the former several specimens were exhibited, including one 4in. long and one 65in. long when fresh. The latter was taken in 22 f. in Loch Nell. Except a dead one 89in. long from the Bergen Fiord this appears to be the largest as yet recorded specimen. It does not appear to be full grown, being much less crowded with polypes than many of the shorter ones. Its lower end was loaded with stiff blue mud when taken.

Polyzoa: many kinds—not identified.

Tunicata: several characteristic forms.

Mollusca: 128 species, besides several Nudibranchs. Fine series of Terebratula caput serpentis, Crania anomala, Pecten niveus and Lima (3 species). Also Pandora obtusa, Emarginula crassa, Trichotropis borealis and Natica helicoides.

Echinodermata 20, including Comatula rosacea in abundance, Amphiura filiformis, Palmipes membranaceus, Brissus lyrifer, Thyone and Sipunculus.

Annelida: a large variety.

Crustacea (podophthalmata) 17, including Munida Rondeletii and Eurynome aspera.

Professor A. M. Marshall, M.A., D.Sc., exhibited virgularia mirabilis taken last year at Oban by the Birmingham Natural History Society, and gave a detailed description of the three forms of Pennatulida. He suggested the desirability of the Section undertaking or taking part in similar excursions in future years.

Ordinary Meeting, January 9th, 1883.

H. E. ROSCOE, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

Dr. JOULE said that he had, in December, 1882, made a fresh determination of the freezing point in a sensitive thermometer constructed 39 years ago. During that time the point had risen about 1° Fahrenheit, and although now rising very slowly, was not even yet quite stationary, having risen $\frac{1}{40}$ of a degree Fahrenheit since November, 1879.

Ordinary Meeting, January 23rd, 1883.

J. P. JOULE, D.C.L., LL.D., F.R.S., &c., Vice-President, in the Chair.

"Remarks on the Simultaneous Variations of the Barometer recorded by the late John Allan Broun," by Professor BALFOUR STEWART, F.R.S.

In the Proceedings of the Royal Society for May 11th, 1876, will be found an account by Broun of simultaneous barometric fluctuations at Singapore, Madras, and Simla, extending over the first three months of 1845. One of these, a maximum, was likewise shown by Broun to have occurred nearly simultaneously on March 31st, at a great many stations in both hemispheres.

The object of these few remarks is to ascertain, quite apart from any theoretical considerations, whether such apparently cosmical fluctuations have any relation to the state of the sun with respect to spots. The spotted areas of the solar surface corresponding to these three months are derived from observations by Schwabe, which will be found recorded in an appendix to the report of the Solar Physics Committee. The unit is one millionth of the sun's visible hemisphere.

Let us now take the epochs of the various barometrical maxima and minima given by Broun, and record the state of the solar surface corresponding to each epoch, and also to the two days before and the two days after each epoch. This is done in the following table, in which the central number always corresponds to the barometric epoch, and in which the numbers enclosed in brackets denote interpolated sun spot values.

TABLE I.—BAROMETRIC MAXIMA.

Barometric epoch. 1845.	Sun Spot Areas.				
Jan. 8	(400)	(470)	540	840	180
,, 12	180	72	660	918	414
Feb. 7	(0)	12	30	24	546
,, 14	(555)	750	(800)	(850)	900
,, 25	894	1452	972	(786)	600
March 7	888	360	(255)	150	330
,, 14	(702)	816	648	(489)	330
,, 31	(0)	210	612	990	996
Sum	3619	4142	4517	5047	4296

TABLE II.—BAROMETRIC MINIMA.

Barometric epoch. 1845.	Sun Spot Areas.				
Jan. 10	540	840	180	72	660
,, 15	918	414	330	(246)	(162)
,, 31	(461)	480	(360)	240	(216)
Feb. 11	546	(453)	360	(555)	750
,, 21	930	882	(886)	(890)	894
March 4	780	702	804	888	360
,, 24	336	(238)	(140)	42	36
April 3	990	996	750	600	540
Sum	5501	5005	3810	3533	3618

It will be seen from these tables that barometric maxima appear to correspond to increasing sun spot values, while barometric minima appear to correspond to decreasing sun spot values; the observations are not, however, sufficiently extensive to render these conclusions certain. It would, I think, be of importance to pursue this investigation.

A paper was read entitled "Jeremiah Horrox and William Crabtree, the Observers of the Transit of Venus in 1639," by Mr. JOHN E. BAILEY, F.S.A.

Mr. BAILEY also exhibited the rare work of Hevelius entitled *Mercurius in Sole visus Gedani 1661*, printed at Dantzic in 1662.

Ordinary Meeting, February 6th, 1883.

Professor BALFOUR STEWART, LL.D., F.R.S., in the Chair.

Among the donations announced were medallion portraits of Mr. George Walker, one of the Founders of the Society, and Mrs. Walker, presented by the President and other members of the Council.

On the motion of Mr. BAXENDELL, seconded by Mr. BAILEY, it was resolved, "That the thanks of the Society be given to the President and other members of the Council for the portraits of Mr. George Walker and Mrs. Walker, presented by them to the Society."

"Note on the Vapours of Incandescent Solids," by HENRY WILDE, Esq.

It is generally admitted that the phenomena known as Moser's Spectral Images, which make their appearance on polished metallic surfaces when bodies are placed very close thereto, are attributable to the general property which solid bodies possess of giving off vapours of their own substance at common temperatures, and the peculiar odours emitted by some of the less volatile metals, such as copper, when subjected to friction or to the action of cutting tools, are also assignable to the like cause.

The production of Moser's images, as has been shown, is greatly assisted by the application of heat, and it might have been anticipated that at high temperatures the most dense and refractory substances would vaporise while retaining their solid form.

The conditions necessary for observing the behaviour of solids at high temperatures are well brought about in the modern form of incandescent electric lamp. This lamp consists of a bulb of glass from which the air is exhausted to the highest degree attainable, and a filament of metal or carbon is mounted in the bulb, and rendered incandescent by the action of the electric current.

Platinum, from its high degree of infusibility, was considered by some the most suitable substance for the luminous filament, and great expectations were formed, that by its use the problem of incandescent lighting would be solved. It was, however, found that an atmosphere of platinum vapour was formed in the interior of the bulb, which, after the lamp had been in action a lengthened number of hours, condensed on the surface of the glass and formed a bright reflecting surface like a mirror.

This property of the platinum, while affording a remarkable illustration of the vaporisation of a dense body while retaining its solid form, was fatal to its use as an illuminant, as the density of the film of platinum on the surface of the glass ultimately obstructed the greater portion of the light from the filament itself.

Chemists, I believe, are not unanimous in opinion as to whether elementary carbon ever passes from the solid to the liquid form.

Some years ago, I frequently made the experiment of concentrating upon a small pencil of carbon, two inches long and three twentieths of an inch in diameter, an amount of electric force sufficient to fuse a rod of platinum two feet long and a quarter of an inch in diameter.

The light from the pencil was of intense whiteness, but the carbon showed no signs of fusion, and rapidly diminished in thickness by combination with the oxygen of the air.

The substitution of a filament of carbon for platinum has now placed the incandescent electric light in the rank of recognised illuminants, and when not raised to too high a temperature the carbon filament is very durable. When, however, a high degree of incandescence is attained, an atmosphere of carbon vapour is formed in the interior of the bulb which condenses on the glass and forms a dark lustrous surface which obstructs the light in the same manner as when a filament of platinum was employed.

The behaviour of the carbon and the platinum in each of these lamps clearly shows that the most dense and refractory substances in nature vaporise at high temperatures while still retaining their solid form.

Electric lamps were exhibited by Mr. Wilde showing the condensed platinum and carbon on the interior surfaces of the glass bulbs.

"Remarks on Professor Osborne Reynolds' paper 'On Isochronous Vibrations,'" by ROBERT RAWSON, Esq., Hon. Member, Assoc. I.N.A., Mem. of the London Mathematical Society.

At the ordinary meeting, Nov. 28th, 1882, Professor Osborne Reynolds, M.A., F.R.S., read an interesting paper entitled "On an Elementary Solution of the Dynamical Problem of Isochronous Vibrations." It would seem that the object of this paper is intended to supply a remedy for what the author conceives to be a serious defect in our existing elementary works on Dynamics.

Experience, it appears, has shown Professor Osborne Reynolds that the obscurity in which the principles of Dynamics are enveloped by means of the language and symbols of Differential equations, "stands very much in the way of those who are commencing the study of practical mechanics."

I am not able, from my own experience, to share the views of the author in respect to the charge which is thus made against the use of differential equations in Dynamical questions; on the contrary, I have always been led to believe that it is, has been, will be, in the language of differential equations that the principles of Dynamics have received their greatest development and their most useful applications. Still I am greatly impressed with the truth, viz., that the experience and opinions of so distinguished an authority as is Professor Osborne Reynolds on all questions relating to the application of mathematics to the Physical Sciences, have great weight, and will always command careful attention.

The problem in question is, however, a simple case of Harmonic motion, which is admirably explained and illustrated by:—1. Thomson and Tait (Natural Philosophy, p. 36), 2. The late Professor Clifford (Elements of Dynamics, p. 20), in sufficiently elementary language to suit the comprehension of any student of practical mechanics.

I may state here that Newton was the first to invent and solve this interesting problem in the pages of the *Principia*, and most writers on the dynamics of variable forces since Newton's time have copied his solution, observing that it is exactly the case of a heavy body falling in an open shaft through the diameter of the earth.

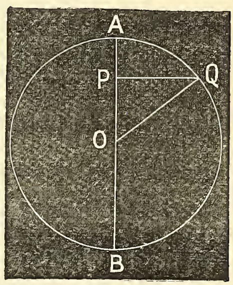
As Professor Osborne Reynolds has, therefore, proposed his solution of this problem with a view of its being inserted in our elementary treatises on Dynamics as the simplest and best which has hitherto been given to suit the requirements of students in practical mechanics, it may not be deemed unnecessary, then, to examine its claims to this distinction, and, if possible, to divest it of a few of those things which tend to increase its complexity and thereby diminish its usefulness.

No exception, however, can be taken either to the principles adopted, or the results derived from them, but, no doubt, the diagram and the process of application of the principles admit of greater simplicity even than that which has been given in the paper. To this end it is necessary to state that the principle and formula of the conservation of energy are given by the simple dynamic of constant forces in such wise as to be comprehended without the aid of differential equations.

The definition of *work* is simple, but, the estimation of it when the force is variable depends upon quadratures.

When, however, the force varies as the distance the estimation of the *work* done by it is given by Moseley, Twisden, and others by elementary mathematics, and is $\frac{1}{2}px^2$, using the notation as given in the paper.

Taking, therefore, for granted a knowledge of the principle and formula for the conservation of energy, the formula for estimating *work* done by a force which varies as the distance from a given point, the resolution and decomposition of forces—the diagram and solution of this problem, will stand as follows.



Let O be the position of a body, whose weight is (w) and velocity (v_0), moving towards A in the straight line BOA where OA = OB. Let (p) represent the force at a unit of distance from O, then (px) will be the force at P, where OP $= x$. Describe the circle about O as centre with the radius OA $= a$, and draw PQ perpendicular to AB meeting the circle in Q. Put (v) the velocity of (w) at P.

Now the *work* done against the force (px) in moving from O to P must be equal to the accumulated *work* lost by passing from (v_0) to (v). Therefore

$$px^2 = \frac{w}{g}(v_0^2 - v^2) \quad \text{.....................} \quad (1)$$

When, however, $v = 0$, then $x = a$, and the weight (w) is at A. On this supposition (1) becomes

$$pa^2 = \frac{w}{g} \cdot v_0^2$$

Substitute this value in (1), then

$$v = \sqrt{\frac{pg}{w}} \cdot \sqrt{a^2 - x^2}$$

$$= \sqrt{\frac{pg}{w}} \cdot PQ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The velocity of (w) is, therefore, greatest at O, and zero at A and B, and will continue to oscillate between A and B so long as the force continues to act.

It will be observed that the motion of Q is compounded of the vertical motion of P and the horizontal motion of the line PQ, then, by the composition of velocities

$$\text{The velocity at } Q = v . \frac{OQ}{PQ} = a\sqrt{\frac{pg}{w}} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Equation (3) shows that Q moves uniformly.

If (t) represents the periodic time, or the time of a complete oscillation, then,

$$a\sqrt{\frac{pg}{w}} . t = 2a\pi$$

$$\text{or, } t = 2\pi\sqrt{\frac{w}{pg}}$$

which is independent of the amplitude of oscillation.

The time of the body describing AP = the time of describing the circular arc $AQ = \sqrt{\frac{w}{pg}} . \text{Sin}^{-1} . \left(\frac{PQ}{a}\right)$.

If the body when at A is slightly struck with a force at right angles to AB it will then describe an ellipse whose centre is 0—this is Newton's case of the problem.

With the above slight alteration in the diagram, the reason for which is given above, the solution of this interesting problem by Professor Osborne Reynolds is simple, accurate, and easy to comprehend by means of elementary mathematics.

On this ground it will no doubt recommend itself to the favourable consideration of any writer on Elementary Dynamics.

Thomas Alcock, M.D., exhibited and explained a series of lithographs of his beautiful drawings illustrating the development of the Common Frog.

Ordinary Meeting, February 20th, 1883.

H. E. Roscoe, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

A communication from Dr. Joule, F.R.S., was read, on the use of lime as a purifier of the products of combustion of coal gas.

The slaked lime is placed in a vessel the bottom of which, about one foot diameter, is slightly domed and perforated with fine holes. The vessel is suspended about six inches above the burner. It is found that a stratum of four or five inches of lime is sufficient to remove the acid vapours so far as to prevent them from reddening litmus paper. The lime seems in many respects to present important advantages over the zinc previously recommended.

Mr. R. D. Darbishire, F.G.S., read a "Note upon the Mammoth Cave," by Mr. G. Darbishire.

After leaving the old "blue grass" formation* to the east

* "The cultivated district of central Kentucky, commonly known as Blue-grass District, is perhaps for its area the most beautiful rural district in America. The surface is undulating, large areas of the original forests have been cleared of their undergrowth, and produce a fine close sod, and in these wood-pastures are some of the finest flocks and herds in the world. It has happened to the writer to pass on several occasions from this region to the richest lands of middle England, or *vice versa*, and he has always been struck by the singular likeness of the two countries. There is probably a closer resemblance between the surface of the country, the cattle, horses, the agriculture, and even the people of these two areas than any two equally remote regions in the world."—From General Account of the Commonwealth of Kentucky (Geological Survey), vol. II. p. xi.

and crossing the Louisville rocks, one approaches the dry lands of the "subcarboniferous formations."*

Here the rainfall is carried off by "sink-holes," and except where important streams flow in open gorges 300 to 350 feet below the plain, the drainage is all under ground. Sink-holes are sometimes isolated funnels in the middle of depressions which might still hold lakes unless so drained, and probably did so once, and sometimes are the outlets at the bottom of dry ravines which have no mouths. The water entering these sink-holes passes away through cracks and caverns hollowed out of the weaker places in the rocks. When such a cavern channel is formed near the surface, the roof falls in at places, and a more or less open ravine appears. At times the sink-holes, after using an upper series of caverns for ages, have drilled downwards by means of the gravel and rock churning in the bottoms of potholes till the water has found lower outlets, and when it has eaten out on lower levels waterways sufficient for the rainfall of the district, the upper caverns are deserted, the muds washed in harden on the

* All this region wants the small valleys which we are accustomed to see in any country; but in their place the surface is covered by broad, shallow, cup-like depressions or sink-holes, in the centre of which is a tube leading down to the caverns below. All this region is completely honeycombed by caverns, one level below the other, from the surface to the plane of the stream below. In one sense this set of underground passages may be regarded as a continuous cavern as extensive as the ordinary branches of a stream when it flows upon the surface. The sink-holes answer to the smallest extremities of the branches. Some idea of the magnitude of these underground ways may be formed from the fact that the Mammoth Cave affords over 200 miles of chambers large enough for the passage of man, while the county in which it occurs has over 500 openings leading far into the earth, none being counted where it is not possible to penetrate beyond the light of day.

floor, and pieces of the roof becoming detached partially fill the unused ways with debris. As this goes on, stalactitic and florescent stalagmitic formations accumulate in these stormless old river channels. The sign of water action in the rocks is wonderfully preserved, and tells its tale of stream-wear or drift-wear more faithfully than in valleys exposed to rains, vegetation, and changes of temperature. The unaccustomed darkness and the strange shadows cast by the lamps of visitors give to these accumulations, masses of debris, and water-worn roofs and walls, weird shapes which are fancifully supposed to resemble familiar objects above ground. Their own individualities, so different from anything on the surface, give them a far stronger claim on the observer's interest.

Amid slightly undulating woodlands about 325 feet above Green River, lies a depression some 80 feet deep, and at one place the sandstone bottom of this depression has fallen away, exposing an opening into the "Mammoth Cave," whose upper and lower chambers are known to extend for 200 miles, and to communicate with further unexplored channels.

After a descent from the open air of about 60 feet, the floor of the "Water Cave" is reached. This has been dry as long as it has been known. Indeed, as it is nearly 200 feet above Green River (the drainage level in this district), the water must for ages have been able to traverse large lower channels.

The old deposits of mud in these upper caves have been so saturated with saltpetre that they have been washed as early as the war of 1812. On the theory that this saltpetre is derived from bat-guano, acted on by the dry atmosphere of the cave, a long period of inaction as a river channel must be allowed for. The number of bats is certainly great, but their lease of the premises during which nitre has been thus accumulated must have been a long one.

For convenience of tourists and guides the caverns are usually visited by what are called the *short* or the *long* routes, about 3½ and 8 miles long respectively. The short route leads for a considerable distance through the main cave amid the workings of the saltpetre diggings. This main cave, nearly four miles in length, has an average width of 60 feet and a height of 40 feet above the present floor, which is formed of debris and alluvial deposits considerably deep over the real rock floor. Owing to peculiar causes in this dry cave, the earth has hardened, and in places the guide points out footprints of the oxen used by the miners not earlier than the beginning of the century, in clay now nearly as hard as rock. The corn-cobs used long ago are still undecayed.

The short route leads visitors from the main cave down by a broken opening to a lower range of caverns in the limestone. These, after passing through various chambers and galleries, lead to a series of "domes and potholes." The "domes," or portions of the potholes extending upwards, are no doubt connected with the funnels of some slough-like depressions in the ground above, and have supplied water to the various levels of caverns in their turn, while the holes having bored some 65 feet lower down, open into the present drainage avenues below. The vertical height of these shafts as visible at present is from 200 to 230 feet, and their diameter about 25 feet, a size due to the cutting power of the gravels in the pothole, and far in excess of anything required by the volume of water to be removed.

On the long route, after leaving the main cave and descending to the "deserted chambers," a second descent leads to the third series of caves, also dry in the present age. Presently the track sounds hollow, and at places, openings in the floor reveal a fourth series of chambers. Descending to these, one reaches the level of medium high-water mark A descent of over 30 feet brought us to the water, which on 1st of November, after the protracted drought, was about 300 feet below the Hotel by my aneroid, or 24 feet above Green River. Here then is reached a cave that is still in use, and the roof shows that these caverns are often quite filled with water.

After crossing several pools, the Echo River is reached, showing a slight current on its surface. The depth of this stream varies from 5 to 10 feet, and its width is from 20 to 200 feet, but probably the deeper parts are nearly still pools. Rowing along this for three quarters of a mile, avenues are next traversed which for a long distance show the mechanical and chemical erosions of the water-flow, and chambers are reached where the roofs and sides are covered with florescent formations of gypsum, the long fibrous bunches of crystal curving outwards from some centre, forming delicate rosettes from 1 to 6 inches in diameter, and as beautiful as flower-like sea anemones; but, unfettered by the bonds of species, every variety of form appears, white, yellow, or black, and all adorned with glittering crystals.

At last, after a scramble over debris (called "the Rocky Mountains,") which has piled up to a height of 200 feet above the water, or a little above the top of the entrance of the main cave, the roof is seen to change. It is above the limestone, and the naked sandstone stretches from side to side. A little further on "the Maelstrom" is reached, another huge pothole, in which the gravels at the bottom are but little above the present water-level, while the dome reaches far up into the sandstone.

On the return journey, a short cut is made up what is called "the Corkscrew." In reality it is a scramble up a cleft in the rocks nearly choked by debris, the top of which is also very near the sandstone. To give an idea of the vastness of this underground drainage I copy from the Guide Book a few dimensions relating to this one cave, and be it remembered that the whole country from Bowling Green to Mufordsville is similarly honeycombed.

The chamber called "Wright's Rotunda" is 400 feet one way and 100 feet wide, while its height is 40 feet.

Mammoth Dome, of a similar length, has a roof of 150 feet span, in the sandstone, and its depth from the bottom of the superincumbent sandstone to the floor is 250 feet.

Ordinary Meeting, March 6th, 1883.

J. P. Joule, D.C.L., LL.D., F.R.S., &c., Vice-President, in the Chair.

Mr. Robert E. Cunliffe and Mr. James Cosmo Melvill were appointed Auditors of the Treasurer's Accounts.

Mr. Wm. Brockbank, F.G.S., referred to the paragraph in the *Daily News* of the 5th, which stated that the waters of the Rhine were so low that the freight boats had ceased running for want of sufficient depth of water, and he pointed out that serious difficulties might be looked for on all the rivers which have their sources in the Alps during the present summer.

The disastrous floods which have prevailed in these rivers were caused by the unseasonable warm winds which blew upon the Alps in the early part of the year, and by which most of the snow below the permanent snow line was melted, causing the rivers and lakes to overflow their banks to an unprecedented extent. These snows were the reservoirs which stored up the summer supplies of water for the Rhine and Danube; their exhaustion has already produced the difficulties alluded to, and which are likely to be more serious in summer time. It is these snows also which feed the alpine glaciers, and a shrinkage of the ice fields will probably follow as summer advances.

"On the Levenshulme Limestones—a Section from Slade Lane eastwards," by W. Brockbank, F.G.S.

In making a deep sewer from Withington to Levenshulme, the strata had been brought to light for about two miles, showing a regular sequence of red measures, commencing in the new red sandstone (trias) at Withington and passing through red clays, shales, and sandstones of the permians, until the Levenshulme limestones at Slade Lane were reached.

Mr. Swarbrick, the Surveyor to the Withington Local Board, had made a section giving the surface of the red measures passed through, which shows it to be much worn and at varying depths, overlain by the lower boulder clay. A deep sewer from Levenshulme to Cringle Brook, to join the above sewer, has been made under the direction of Mr. Harper, the Surveyor to the Levenshulme Local Board, whose working plan and section were also produced, showing the measures which were drifted through in the progress of the works. Commencing at Cringle Brook, where the works of the Withington sewer were met, the drift was in red sandstone, but the limestone was soon after reached and continued for about 750 feet. Some portions of the drifting were through solid limestone rock, the beds being from 1ft. 6in. to 2ft. thick. In other places the measures were much disturbed, a fault being marked on Mr. Harper's plan at one point, and a seam of ironstone 6in. thick also occurred, embedded between the limestones. Red clay was next passed through for about 270 feet, the limestone resting upon it. The course of these works was nearly from south to north, the drift being nearly parallel to the face of the limestones and apparently almost upon the top of the outcrop. A little further northwards the lower boulder clay was entered, and shortly after the course of the sewer turned eastwards along Albert Road, passing under the L. and N.W. railway at Levenshulme station, and terminating in the Manchester and Stockport road at Levenshulme. The lower boulder clay occupied the whole of this portion. Endeavours had been made to ascertain the depth of the clay in this part of the section, but it could not be ascertained. Mr. Worthington, the Engineer of the L. and N.W. railway, under whose superintendence some large bridges had just been erected at Levenshulme, had stated that although a solid foundation had been sought for, nothing but clay had been met with to a considerable depth. At Levenshulme Printworks, about half a mile further eastwards, an artesian well was sunk some years ago, and by the kindness of Mr. Thomas Aitken the diagram section was now produced, showing the following measures to have been passed through :

SECTION OF BORING AT LEVENSHULME PRINT WORKS.

	ft.	in.
Boulder Clay.		
Clay	32	0
Sand	3	6
Quicksand	1	0
Clay	9	6
Clay	31	0
Sand and Gravel	5	0
	82	0
Trias.		
Red Sandstone, very soft	12	0
Red Sandstone	83	0
Red Ruddle	8	6
Red Sandstone	24	0
Red Marl	4	0
Red Sandstone	34	4
Red Shale	0	1½
Red Sandstone	57	2
Red Marl	1	6
Red Sandstone	31	4
Red Clay	2	6
Coarse Red Sandstone with Pebbles...	39	6
Red Clay	2	6
Red Sandstone	47	2
Solid Red Rock	3	0
Red Sandstone	17	0
Total	449	7½

It will be seen that the boulder clay and sands were 82 feet thick at the Levenshulme Printworks, and that the new red sandstones continued to a depth of 450 feet, when water was met with (of excellent quality) in the pebble beds. Half a mile further eastwards, near Sandfold, some borings were taken with a view to the erection of Sir Joseph Whitworth's works on that site; but although no accurate record was kept, I have learned that clay and sand were found to a great depth, so that no solid foundation for steam hammers could be obtained:—thus showing that a similar depth of clay probably prevails over a considerable area. At Sandfold the upper clays come upon the section, the sands being largely developed there between the upper and the lower clays, and producing much water. It is interesting to note that a Roman cinerary urn was found at Sandfold, a portion of which is in Mrs. Aitken's possession.

The section therefore commences on the west with New Red sandstone at Withington, and terminates westward in the same. The fault at Slade Lane brings the Levenshulme limestone nearly to the surface with (probably) the new red sandstone in front of it eastwards, and the Permian measures westwards, dipping under the Trias at Withington.

The great fault which brings up the Levenshulme limestone is shown in Mr. Binney's diagram of the section from Heaton Mersey to Goyt Hall beyond Stockport, and appears to be the great boundary fault of the Manchester coal field, which is seen at Collyhurst and Heaton Norris. At the latter point it is marked on the Ordnance Survey as being a downthrow to the east of 200 yards, but at Slade Lane it would appear to be rather an upthrow fault to the west. It is quite clear that the recent discoveries at Withington and Levenshnlme will necessitate a careful resurvey of the district, as the present maps do not show correctly the lines of faults, nor the areas covered by the Permians, as recently brought to light. A considerable quantity of large blocks of Levenshulme limestone have been removed to the gardens at Brockhurst, Didsbury, where they have been permanently placed, so as to be accessible to all interested in the study of them. They bear evidence of having formed an outcrop of limestone for some time before they were finally covered up by the boulder drift clays. Many of the blocks are much weathered upon several surfaces, as if they had formed the top of a hill, like the creviced summit of a limestone crag. Others are planed quite smooth, showing the veins of spar as in polished marble, and have probably formed a floor, over which the grinding force of the boulder drift passed. One large block shows very clearly the effect of glacial action, having well marked striæ and a smoothly polished surface; and others are rounded and worn, as if they had been knocked about a good deal. They thus bear evidence of the forces to which they have been subjected, and are interesting illustrations of glacial action. They also contain many fossils.

Joint Meeting of the Microscopical and Natural History Section and the Parent Society.

January 15th, 1883.

James Cosmo Melvill, M.A., F.L.S., President of the Section, in the Chair.

Mr. Rogers exhibited a slide of the Lingual Palate of Trochus Milligranus stained in nitrate of silver, and mounted in dammar.

Mr. J. C. Melvill exhibited a specimen of the rare Goliath Beetle Goliathus Druryi (Westwood), captured by a sailor on a palm tree near the Cameroon Mountains in Western Africa.

Mr. Charles Bailey mentioned that last summer he had noticed the blue Pimpernel Anagallis Cerulæa growing in the garden of the Whalley Hotel, Brooks's Bar.

Professor A. M. Marshall gave some particulars of the dredging excursions conducted by the Birmingham Natural History Society, and proposed that the Section should organise a dredging excursion during the coming summer. After some discussion, in which Mr. R. D. Darbishire, Mr. C. Bailey, Dr. Alcock, Mr. Melvill, and Mr. Stirrup took part, it was resolved on the motion of Professor Marshall, seconded by Mr. Stirrup:—"That a Committee be formed to make enquiries and report upon the best method of carrying out such an expedition."

And upon the motion of Mr. Rogers, seconded by Mr. J. Boyd:—"That the Committee be composed of Mr. J. C. Melvill, Mr. R. D. Darbishire, Dr. Marshall, Mr. Stirrup, Dr. Alcock, and Mr. C. Bailey.

Mr. R. D. Darbishire exhibited a series of land and fresh-water Shells, from Budapesth, with corresponding English species for comparison.

MICROSOPICAL AND NATURAL HISTORY SECTION.

12th February, 1883.

James Cosmo Melvill, M.A., F.L.S., President of the Section, in the Chair.

The Secretary announced the presentation to the Section by T. R. Archer Briggs, F.L.S., of a copy of his "Flora of Plymouth," and by Messrs. Melvill and Bailey of the "Journal of Botany," in monthly parts as issued.

Mr. J. C. Melvill exhibited a dwarf specimen of the common Harebell Campanula Rotundifolia, having the corolla divided into five equal lingulate segments down to the base, found on Afton Down, Isle of Wight.

Also specimens of Calamintha Sylvatica, Blomf., and Campanula Glomerata, L., var. Nana Bailey, and of Erythræa Capitata, Willd., var. Sphærocephala, Townsend, one of the rarest British plants.

Dr. Alcock read a paper on the Structure of the Shells of several common species of Polymorphina, and exhibited specimens and drawings to illustrate his remarks. He showed, by transparent specimens mounted in balsam, that in all cases the walls of the inner chambers which have become enclosed by later growths are to a considerable extent removed by absorption, opening out the interior into one large cavity, and that in P. oblonga and P. gibba this absorption is remarkably well seen.

By endeavouring to form an idea of the mode of growth of these shells in relation to the life of the contained animal, he had been led to doubt the distinctness of P. lactea and P. compressa as species, the former apparently being P. compressa in the young state; and he could not avoid the conclusion that P. oblonga is widely separated by its characters from P. lactea, the two most prominent of these characters being the erect oblong segments all extending to the base of the shell, and the inverted tube at the mouth.

With regard to P. Orbignii, the exhibited specimens of which were P. gibba with the peculiar wild-grown last chamber, he still thought his formerly expressed opinion (Memoirs Lit. and Phil. Soc., Manchester, vol. 3, third series, 1866-67) was correct, namely, that the formation of an irregular shell-covering over the external sarcode in two or three broad arched passages with numerous tubes for the protrusion of pseudo-podia, was due to failing power in the animal owing to advanced age. In P. gibba the most clearly expressed idea in the structure is strength, and ability to resist rough usage, as is seen both in the rounded pebble-like shape, and in the absorption of the interior walls with redeposit of the shell-matter on the exterior; and it would seem that the best proof of vigour in the animal is the regular formation of successive chambers on this globular plan; requiring, as in other regular foraminifera, an active contraction and collection of the external sarcode into the correct shape and position to form each new chamber; whilst neglect to do this, until a shell-covering has formed upon it, in a shape the least capable of resisting injury, can scarcely be referred to anything but enfeebled vital power.

Ordinary Meeting, March 20th, 1883.

J. P. Joule, D.C.L., LL.D., F.R.S., &c., Vice-President, in the Chair.

A discussion, commenced by Professor Reynolds, took place on the effects of the explosion at the Local Government Board offices, on the 15th instant.

General Meeting, April 3rd, 1883.

H. E. Roscoe, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

Mr. James Rhodes, M.R.C.S., of Glossop, was elected an Ordinary Member of the Society.

Ordinary Meeting, April 3rd, 1883.

H. E. Roscoe, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

The President exhibited the ash of burnt diamonds, and enlarged drawings of the same.

"On the Occurrence of Caffeine in the leaves of Tea and Coffee grown at Kew Gardens," by C. Schorlemmer, F.R.S.

Some time ago I wanted some information on the plants containing caffeine. This interesting compound is not only found in the seeds of *Coffea arabica,* but also in the fleshy part of the berry and in the leaves. The latter are used in Sumatra by the natives in the place of tea, and some years ago a patent was taken out for the introduction of "Coffee-tea" into this country, but it has not been successful.

Caffeine also occurs in the leaves of different species or varieties of tea; in Paraguay-tea, consisting of the leaves and small twigs of *Ilex paraguayensis*; and in Guarana or Brazilian chocolate, which is obtained from the roasted seeds of *Paullinia sorbilis.* It has further been found in Colanuts, the seeds of *Sterculia acuminata,* which are extensively used as a condiment by the natives of western and central tropical Africa; and likewise by the negroes in the West Indies and Brazil, by whom the tree has been introduced in these countries. It is said that they promote digestion, improve the flavour of anything eaten after them, to counteract the effects of alcohol, and even to render half-putrid water drinkable. Cola-nuts contain also theobromine, which is a very interesting fact, inasmuch as this base, which was first found in *Theobroma Cacao,* belonging also to the *Sterculiaceæ,* can be easily transformed into Caffeine.

In collecting this information I consulted, amongst other works, "the Treasure of Botany," edited by Lindley and Moore, where I found the statement, that the custom of drinking coffee originated with the Abyssinians, who cultivated the plant from time immemorial. In Arabia it was not introduced until the early part of the fifteenth century; before this time the beverage made from the leaves of the kât (*Catha edulis*) was generally used, and is still in use, possessing properties resembling those of strong green tea, only more pleasing and agreeable. The leaves are also chewed, and are said to have the effect of producing great hilarity of spirits, and such an agreeable state of wakefulness, that the Arabs who chew them are able to stand sentry all night long without feeling drowsy.

As the properties of kât resemble so much those of tea, it appeared to me highly probable that they contain caffeine. My friend, Mr. H. Marshall Ward, was kind enough to apply to Professor W. T. Thistleton Dyer, F.R.S., who supplied me in the beginning of December with fresh leaves of a plant growing in the temperate house at Kew Gardens. He also sent me a sample from the museum. He says:—"The material in our museum is not very satisfactory, but I enclose a portion of an authentic sample. The leaves are different in form from those of the living plant, but I have ascertained that in this respect they are variable."

I first examined the fresh leaves; not a trace of caffeine could be found, while its presence can be easily shown in three or four tea-leaves. The only crystalline compound which I could extract from Catha was a kind of sugar, apparently Mannite. The quantity was, however, too small for identifying it.

No caffeine could be detected in the authentic sample, but it contained common salt, showing that it must have been in contact with sea water.

As I fully expected to find caffeine and was disappointed, it occurred to me that possibly the leaves of tea and coffee grown at Kew might also not contain their characteristic principle.

Professor Dyer kindly supplied me with the fresh leaves of several varieties and species in the middle of February.

I found caffeine in green tea (*Thea viridis*) and in Assam tea (*T. assamica*).

The leaves of *Coffea arabica*, which is now fruiting in the gardens, contain it also, but much less in proportion than tea.

In *Coffea laurina* I found a trace, but none at all in the large old leaves of Liberian coffee.

Caffeine and theobromine occur only in the vegetable kingdom. They are nearly related to uric acid, guanine, and xanthine, which are products of the material exchanges of the animal organism. The two former can be converted into xanthine, and this, as Professor E. Fischer has shown, into theobromine or methylxanthine, and into caffeine or dimethylxanthine.

As caffeine is used in medicine, it appears very probable that in no distant time it will be manufactured from Peruvian guano, which is the best source for guanine.

Annual General Meeting, April 17th, 1883.

H. E. Roscoe, Ph.D., LL.D., F.R.S., &c., President, in the Chair.

The following Donations to the Funds of the Society were announced, and the thanks of the Society voted to the Donors:

Dr. R. Angus Smith, F.R.S.	£50
Henry Wilde, Esq.	100
Dr. J. P. Joule, F.R.S.	50
Dr. James Young, F.R.S.	50
Dr. H. E. Roscoe, F.R.S.	50

Report of the Council, April, 1883.

The Treasurer's annual statement attached to this report shows that the balance against the General Account has been reduced from £120 13s. 3d.—at which it stood on the 31st March, 1882—to £92 2s. 10d. on the 31st March, 1883. But this improvement is more apparent than real, inasmuch as an item for rental was included in the receipts immediately before the close of the financial year, while the paid arrears of the years 1880-1 and 1881-2, included in this year's account, are larger than they will be in the corresponding period next year. It should also be noticed that the expenditure on account of the Library has been very greatly reduced during the last five sessions, this year's amount having been £17 6s. 7d., as against £145 13s. 6d. expended during the session of 1878-9. On the other hand, the balance in favour of the Natural History Fund on the 31st March, 1883, stands at £55 9s. 11d., as compared with £35 7s. 11d., the amount at which it stood at the corresponding period twelve months previously. The balance in favour of the Compounders' Fund remains stationary at £125, and this item added to the balance of £55 9s. 11d. at the credit of the Natural History Fund, less the adverse balance of £92 2s. 10d. on the General Account, leaves a cash balance of £88 7s. 1d. in the hands of the Society's bankers on the 31st March, 1883.

The monetary position of the Society becomes less satisfactory year by year, and the Treasurer has urged upon the Council the great desirability of largely increasing the number of members as the only sound means of bringing the Society's finances into a more healthy condition. The valuable library which the Society possesses cannot be maintained satisfactorily under a less expenditure than £80 per annum, while the state of the fabric and fittings of the house will, with other heavy obligations, necessitate an outlay which the Society is at present unable to meet.

The number of Ordinary Members on the roll of the Society on the 1st of April, 1882, was 141, and 2 new members have been elected; the losses have been, resignations 3, deaths 2. The number on the roll on the 1st instant was therefore 138. The deceased members are Mr. H. A. Hurst and Mr. J. G. Lynde.

Mr. James Gascoigne Lynde, M. Inst. C.E., was a native of the south of England, and practised for many years as a civil engineer in London as a member of the firm of Lynde and Simpson, George Street, Westminster. In 1857 he was appointed City Surveyor by the Manchester Corporation, which position he retained until his resignation in March, 1879. During the long period Mr. Lynde occupied this position he was regarded by the members of the Corporation with the highest esteem and utmost confidence. Among the more notable undertakings carried out under his supervision were the widening of Deansgate, the improvement of the river Medlock, and the construction of the Corporation Gasworks at Bradford Road. He prepared the plans for laying out Alexandra Park, and, more recently, those for the Southern Cemetery. The Queen's Road Viaduct, the Smedley Road Bridge crossing the river Irk, the Waterloo Bridge which crosses the Irwell in Strangeways, the Irwell Street Bridge in connection with the Quay Street improvement, and the Prince's Bridge which provides communication between Manchester and Salford by way of Hampson Street, Oldfield Road, were all constructed from his designs. Mr. Lynde was one of the oldest members of the Institution of Civil Engineers, having completed his 50th year of membership; he was a Fellow of the Geological Society of London, and a member of the Institute of Mechanical Engineers.

The following papers and communications were read at the Ordinary and Sectional Meetings of the Society during the Session:

October 3rd, 1882.—"On a vitrified mass of stone from the vitrified Fort of Glen Nevis," by Dr. R. Angus Smith, F.R.S., &c.

"On a Compound Rainbow," by R. F. Gwyther, M.A.

October 9th, 1882.—"On a series of preparations from the Coal Measures illustrating the present state of our knowledge of the relations between Lepidodendron, Sigillaria, and Stigmaria," by Professor W. C. Williamson, F.R.S.

October 17th, 1882.—"Note on the Development of Living Germs in Water," by Dr. R. Angus Smith, F.R.S.

"On the Formula for the Intensity of Light transmitted through an Absorbing Medium, as deduced from Experiment," by James Bottomley, B.A., D.Sc.

"On the Intensity of Light that has been transmitted through an Absorbing Medium in which the Density of the Colouring Matter is a function of the distance traversed," by James Bottomley, B.A., D.Sc.

"The Death-age in Langweis (Switzerland)," drawn up by Arthur W. Waters, F.G.S., F.L.S.

October 31st, 1882.—"Belted Skew Pulleys," by Archibald Sandeman, M.A.

"Note on the Dimensions of Ships," by J. P. Joule, D.C.L., LL.D., F.R.S.

"On the Coffee Leaf Disease of Ceylon, illustrated by preparations for examination under the microscope," by H. Marshall Ward, B.A., Fellow of Owens College. Communicated by Professor Osborne Reynolds, F.R.S.

November 14th, 1882.—"On Singular Solutions of Differential Equations," by Robert Rawson, Esq., Hon. Mem., Assoc.I.N.A., Mem. of the London Mathematical Society.

November 28th, 1882.—"On the Transformation of a Logical Proposition containing a Single Relative Term," by Joseph John Murphy, F.G.S. Communicated by the Rev. Robert Harley, F.R.S.

December 12*th*, 1882.—"On an Elementary Solution of the Dynamical Problem of Isochronous Vibration," by Prof. Osborne Reynolds, M.A., F.R.S.

"On the Occurrence of *Potamogeton Zizii*, M. and K., in Lancashire, and in Westmoreland," by Charles Bailey, F.L.S.

"On the Lincolnshire locality for *Selinum Carvifolio*, L.," by Charles Bailey, F.L.S.

"On some of the Results of a Dredging Excursion at Oban," by R. D. Darbishire, F.G.S.

January 9*th*, 1883.—"On the Change of the Freezing Point of a Sensitive Thermometer constructed 39 years ago," by J. P. Joule, D.C.L., LL.D., F.R.S., &c.

January 23*rd*, 1883.—"Remarks on the Simultaneous Variations of the Barometer recorded by the late John Allan Broun," by Professor Balfour Stewart, F.R.S.

"Jeremiah Horrox and William Crabtree, the Observers of the Transit of Venus in 1639," by Mr. John E. Bailey, F.S.A.

February 6*th*, 1883.—"Note on the Vapours of Incandescent Solids," by Henry Wilde, Esq.

"Remarks on Professor Osborne Reynolds' paper on Isochronous Vibrations," by Robert Rawson, Esq., Hon. Mem., Assoc.I.N.A., Mem. of the London Mathematical Society.

February 12*th*, 1883.—"On the Structure of the Shells of several common species of Polymorphina," by Thomas Alcock, M.D.

February 20*th*, 1883.—"On the use of Lime as a purifier of the products of combustion of Coal Gas," by J. P. Joule, D.C.L., LL.D., F.R.S.

"Note on the Mammoth Cave," by Mr. G. Darbyshire.

March 6*th*, 1883.—"On the low state of the waters of the Rhine," by Wm. Brockbank, F.G.S.

"On the Levenshulme Limestones—a Section from Slade Lane eastwards," by Wm. Brockbank, F.G.S.

April 3*rd*, 1883.—"On the Ash of the Diamond, by Professor H. E. Roscoe, LL.D., F.R.S., &c., President.

"On the Occurrence of Caffeine in the leaves of Tea and Coffee grown at Kew Gardens," by Professor C. Schorlemmer, F.R.S.

Several of these papers have been passed by the Council for printing in the Society's Memoirs, and will appear in volume 8. In addition to volume 8, which is in progress of formation, a Memoir, consisting of a History of the Society since its foundation in 1781, by Dr. Angus Smith, undertaken at the request of the Society on the occasion of its Centenary in 1881, will appear as volume 9.

The Council again consider it desirable to continue the system of electing Sectional Associates, and a resolution on the subject will, as usual, be submitted to the Annual Meeting for the approval of the members.

Dr.

Charles Bailey, Treasurer, in account with the Socie
Statement of the Accou

1883.	£	s.	d.	1882-3. £	s.	d.	1881- £	s.
To Cash in hand, 1st April, 1882				39	14	8	111	5
To Members' Contributions :—								
Arrears 1880-1, 4 Subscriptions at 42s.	8	8	0					
,, 1881-2, 18½ ,, ,,	38	17	0					
,, ,, 1 Admission Fee ,,	2	2	0					
Old Members, 1882-3, 121 Subscriptions	254	2	0					
New Members, ,, 2 ,,	4	4	0					
,, ,, ,, 2 Admission Fees	4	4	0					
Old Member, 1883-4, 1 Subscription	2	2	0					
				313	19	0	305	11
To One Associate's Library Subscription				0	10	0	0	10
To Sectional Contributions for 1882-3 :—								
Physical and Mathematical Section	2	2	0					
Microscopical and Natural History Section	2	2	0					
				4	4	0	4	4
To use of the Society's Rooms :—								
Geological Society to 31st March, 1882	30	0	0					
,, ,, ,, 1883	30	0	0					
				60	0	0	30	0
To Sale of the Society's Publications				5	11	1	8	10
To Repayment of cost of Periodicals (Physical Section)				0	5	10		
To Natural History Fund :—								
Dividends on £1,225, Gt. Western Ry. Co.'s Stock				59	13	9	54	18
To Bank Interest, less Bank postages				2	14	7	2	14
				£486	12	11	£517	13

1883.—April 1. To Cash in Manchester and Salford Bank, Limited................. £88 7

Note.—The detailed accounts of the session 1882-3 (of which the above account is a
abstract) were audited by Mr. Robt. E. Cunliffe and Mr. J. Cosmo Melvill, on t
4th April, 1883, and have been found correct.

ILOSOPHICAL SOCIETY.

I 1st April, 1882, to the 31st March, 1883, with a Comparative
the Session 1881-1882.

Cr.

83—March 31.	1882-3. £ s. d.	£ s. d.	1881-2. £ s. d.	£ s. d.
Charges on Property:—				
Chief Rent	12 12 2		12 12 8	
Insurance against Fire	12 17 6		12 17 6	
Property Tax	4 12 1		3 10 10	
Repairs, &c.	1 3 3		3 6 5	
		31 5 0		32 7 5
House Expenditure:—				
Coals, Gas, Candles, and Water	15 13 1		17 11 4	
Tea and Coffee at Meetings	15 9 6		17 1 10	
House Duty	6 7 6		6 7 6	
Cleaning, Brushes, &c.	5 10 1		5 6 8	
		43 0 2		46 7 4
Administrative Charges:—				
Wages of Keeper of Rooms	57 4 0		57 4 0	
Postages and Carriage of Parcels	16 19 1		18 12 0	
Attendance on Sections and Societies	9 4 0		9 9 0	
Stationery and Printing Circulars	10 17 6		14 2 1	
Distributing Memoirs	... ...		3 0 0	
		94 4 7		102 7 1
Publishing:—				
Printing Memoirs	75 19 3		51 9 0	
Printing Proceedings	43 13 0		54 1 0	
Wood Engraving and Lithographing	3 5 6		1 11 6	
Editor of Memoirs and Proceedings	50 0 0		50 0 0	
		172 17 9		157 1 6
Library:—				
Binding Books	... ...		... ...	
Books and Periodicals	7 16 1		22 4 8	
Assistant in Library	9 0 0		19 12 6	
Geological Record for the Year 1878	0 10 6		... ...	
Palæontographical Society	... ...		1 1 0	
Ray Society	... ...		1 1 0	
		17 6 7		43 19 2
Natural History:—				
Works on Natural History	9 16 9		15 16 5	
Lithographing and Printing Plates of Paper on Frog	29 15 0		... ...	
Grant to Microscopical Natural History Section	... ...		80 0 0	
		39 11 9		95 16 5
Balance		88 7 1		39 14 8
		£486 12 11		£517 13 7

	1882-3. £ s. d.	£ s. d.
mpounders' Fund:—		
Balance in favour of this Account, April 1st, 1883		125 0 0
tural History Fund:—		
Balance in favour of this Account, April 1st, 1883	35 7 11	
Dividends received during Session 1882-3	59 13 9	
	95 1 8	
Expenditure during Session 1882-3	39 11 9	
Balance in favour of this Account, 31st March, 1883		55 9 11
		180 9 11
neral Fund:—		
Balance against this Account, 1st April, 1882	120 13 3	
Expenditure during the Session 1882-3	358 14 1	
	479 7 4	
Receipts during the Session 1882-3	387 4 6	
Balance against this Account, 31st March, 1883		92 2 10
sh at Bankers, 31st March, 1883		£88 7 1

MANCHESTER LITERARY AN OSOPHICAL SOCIETY.

Charles Bailey, Treasurer, in account with the Society April, 1882, to the 31st March, 1883, with a Comparative Statement of the Account Session 1881-1882.

Dr.

	£ s. d.	1882-3. £ s. d.	1881-2. £ s. d.
1883.			
To Cash in hand, 1st April, 1882		39 14 8	111 5
To Members' Contributions :—			
Arrears 1880-1, 4 Subscriptions at 42s.	8 8 0		
„ 1881-2, 18½ „ „	38 17 0		
„ „ 1 Admission Fee „	2 2 0		
Old Members, 1882-3, 121 Subscriptions	254 2 0		
New Members, „ 2 „	4 4 0		
„ „ „ 2 Admission Fees	4 4 0		
Old Member, 1883-4, 1 Subscription	2 2 0	313 19 0	305 11
To One Associate's Library Subscription		0 10 0	0 10
To Sectional Contributions for 1882-3 :—			
Physical and Mathematical Section	2 2 0		
Microscopical and Natural History Section	2 2 0	4 4 0	4 4
To use of the Society's Rooms :—			
Geological Society to 31st March, 1882	30 0 0		
„ „ „ 1883	30 0 0	60 0 0	30 0
To Sale of the Society's Publications		5 11 1	8 10
To Repayment of cost of Periodicals (Physical Section)		0 5 10	
To Natural History Fund :—			
Dividends on £1,225, Gt. Western Ry. Co.'s Stock		59 13 9	54 18
To Bank Interest, less Bank postages		2 14 7	2 14
		£486 12 11	£517 13 7

1883.—April 1. To Cash in Manchester and Salford Bank, Limited £88 7 1

Note.—The detailed accounts of the session 1882-3 (of which the above account is abstract) were audited by Mr. Robt. E. Cunliffe and Mr. J. Cosmo Melvill, on 4th April, 1883, and have been found correct.

Cr.

	1882-3. £ s. d.	£ s. d.	1881-2. £ s. d.	£ s. d.
-March 31.				
rges on Property :—				
ief Rent	12 12 2		12 12 8	
urance against Fire	12 17 6		12 17 0	
operty Tax	4 12 1		3 10 10	
pairs, &c.	1 3 3	31 5 0	3 6 5	32 7 5
use Expenditure :—				
als, Gas, Candles, and Water	15 13 1		17 11 4	
a and Coffee at Meetings	15 9 6		17 1 10	
use Duty	6 7 6		6 7 6	
aning, Brushes, &c.	5 10 1	43 0 2	5 6 8	46 7 4
ministrative Charges :—				
ges of Keeper of Rooms	57 4 0		57 4 0	
stages and Carriage of Parcels	16 19 1		18 12 0	
tendance on Sections and Societies	9 4 0		9 9 0	
tionery and Printing Circulars	10 17 6		14 2 1	
stributing Memoirs	... ...	94 4 7	3 0 0	102 7 1
blishing :—				
inting Memoirs	75 19 3		51 9 0	
nting Proceedings	43 13 0		54 1 0	
od Engraving and Lithographing	3 5 6		1 11 6	
litor of Memoirs and Proceedings	50 0 0	172 17 9	50 0 0	157 1 6
brary :—				
nding Books	... ...		... ...	
oks and Periodicals	7 16 1		22 4 8	
sistant in Library	9 0 0		19 12 0	
ological Record for the Year 1878	0 10 6		... ...	
ontographical Society	... ...		1 1 0	
y Society	... ...	17 6 7	1 1 0	43 19 2
tural History :—				
orks on Natural History	9 16 9		15 16 5	
thographing and Printing Plates of Paper on Frog	29 15 0		... ...	
rant to Microscopical Natural History Section	... ...	39 11 9	80 0 0	95 16 5
alance		88 7 1		39 14 8
		£486 12 11		£517 13 7

	1882-3. £ s. d.	£ s. d.
unders' Fund :—		
alance in favour of this Account, April 1st, 1883		125 0 0
History Fund :—		
alance in favour of this Account, April 1st, 1883	35 7 11	
ividends received during Session 1882-3	59 13 9	
	95 1 8	
xpenditure during Session 1882-3	39 11 9	
alance in favour of this Account, 31st March, 1883		55 9 11
		180 9 11
al Fund :—		
alance against this Account, 1st April, 1882	120 13 3	
xpenditure during the Session 1882-3	358 14 1	
	479 7 4	
eceipts during the Session 1882-3	387 4 6	
alance against this Account, 31st March, 1883		92 2 10
t Bankers, 31st March, 1883		£88 7 1

On the motion of the Rev. WILLIAM MARSHALL, seconded by Mr. HARRY GRIMSHAW, the Report was unanimously adopted, and ordered to be printed in the Society's Proceedings.

On the motion of Mr. ALFRED BROTHERS, seconded by Mr. JAMES SMITH, it was resolved unanimously:—

That the system of electing Sectional Associates be continued during the ensuing Session.

The following gentlemen were elected officers of the Society and members of the Council for the ensuing year:—

President.

HENRY ENFIELD ROSCOE, B.A., PH.D., LL.D., F.R.S., F.C.S.

Vice-Presidents.

JAMES PRESCOTT JOULE, D.C.L., LL.D., F.R.S., F.C.S.
EDWARD SCHUNCK, PH.D., F.R.S., F.C.S.
ROBERT ANGUS SMITH, PH.D., LL.D., F.R.S., F.C.S.
REV. WILLIAM GASKELL, M.A.

Secretaries.

JOSEPH BAXENDELL, F.R.A.S.
OSBORNE REYNOLDS, M.A., F.R.S.

Treasurer.

CHARLES BAILEY, F.L.S.

Librarian.

FRANCIS NICHOLSON, F.Z.S.

Other Members of the Council.

OBERT DUKINFIELD DARBYSHIRE, B.A., F.G.S.
BALFOUR STEWART, LL.D., F.R.S.
CARL SCHORLEMMER, F.R.S.
JAMES BOTTOMLEY, B.A., D.Sc., F.C.S.
WILLIAM HENRY JOHNSON, B.Sc.
HENRY WILDE.

"A Proof of the Addition Theorem in Elliptic Integrals," by R. F. Gwyther, M.A.

The quadriquadratic equation, symmetrical and of even order

$$A + B(x^2 + y^2) + 2Cxy + Dny^2 = 0$$

may be used to perform the actual addition of two elliptic integrals of the normal form.

Taking the integral $\displaystyle\int_o^b \frac{dx}{\sqrt{(1-x^2)(1-k^2x^2)}} \equiv \int_o^b \frac{dx}{\Delta(x.k)}$

we will use the above equation to obtain a substitution giving as result an integral of the same form, and having for its lower limit the value a.

Solve the quadriquadratic for x and y respectively

$$(B + Dy^2)x + Cy = \pm\sqrt{-AB + (C^2 - B^2 - AD)y^2 - BDy^4}$$
$$(B + Dx^2)y + Cx = \sqrt{-AB + (C^2 - B^2 - AD)x^2 - BDx^4}.$$

Now choose the constants in the equation of transformation so that the radicals become $\Delta(g.k)$ and $\Delta(x.k)$ respectively. This requires

$$-AB = 1\,; \quad -BD = k^2, \text{ \&c.}$$

Also the equation connecting the variations of x and y is

$$\frac{dx}{(B + Dx^2)y + Cx} + \frac{dy}{(B + Dy^2)x + Cy} = 0,$$

$$\text{or,} \quad \frac{dx}{\Delta(x.k)} \pm \frac{dy}{\Delta(y.k)} = 0.$$

In considering the limits of y corresponding to the given values of x, the lower is to be a, and we will call the upper c. This limit is to be expressed in terms of a and b.

From the solved forms of the quadratics we get

$$\left(\text{putting } \begin{matrix} x = o \\ y = a \end{matrix}\right\} \quad \left.\begin{matrix} x = b \\ y = c \end{matrix}\right\} \text{ simultaneously}\Bigg)$$

$$Ca = \pm\Delta(a.k)$$
$$Ba = 1$$
$$(B + Db^2)c + cb = \Delta(b.k)$$
$$\text{with} \quad BD = -k^2.$$

Hence $D = -k^2 b$, and

$$(1 - k^2a^2b^2)c = a\,\Delta\,(b.k) \mp b\,\Delta\,(a.k)$$

taking the upper or lower sign throughout.

$$\therefore \int_o^b \frac{dx}{\Delta\,(x.k)} = \mp \int_b^c \frac{dy}{\Delta\,(y.k)} = \mp \int_b^c \frac{dx}{\Delta\,(x.k)}$$

and ultimately

$$\int_o^a \frac{dx}{\Delta\,(x.k)} \pm \int_o^b \frac{dx}{\Delta\,(x.k)} = \int_o^c \frac{dx}{\Delta\,(x.k)}$$

where $c = \dfrac{a\,\Delta\,(b.k) \pm b\,\Delta\,(a.k)}{1 - k^2a^2b^2}$

according as the upper or lower sign is taken.

"Observations made in St. Moritz* in the Winter 1882-3," by Arthur Wm. Waters, F.G.S., F.L.S.

Knowing that the session of the Society will soon close I hasten to put together a few of my winter observations in order that they may be read at the closing Meeting.

Much of my time has been occupied in preparing new instruments adapted for the climate, and therefore my observations are few and imperfect, but I have tried to obtain a few figures bearing upon the question of the influence of a snow covering upon climate. This can only be worked out after many years' observations, but I hope that some of the points noticed will afterwards be of considerable use, and perhaps the most interesting are those on the temperature indicated by a thermometer placed in the snow.

The thermometer used was a common one painted white over the bulb, and which I carefully tested for the freezing point, but some of the lower degrees may not be absolutely correct. It was placed vertically with the bulb about 25 centimetres below the surface and with the upper part one or two inches below the surface, and there will all through the winter have been at least half a metre of snow between the bulb and the earth.

* St. Moritz, the highest village in the Engadine, is 6089 feet above the sea.

There are a great many difficulties about such observations, as, first, the condition of the snow is very variable, and the thermometer must to a certain extent be influenced by conduction. If it could be managed, the thermometer ought to be placed horizontally; but practically this would be more difficult, as the condition of the snow in arranging it would be too much disturbed for constant observations. In order to test this, besides what I call the permanent thermometer, I placed one about an inch below the surface and another about a foot below; on February 22nd, for instance, at 11.30 a.m., the one 1 inch below showed 30·8 F., the permanent one 23·7 F., and the one 1 foot below 25 F. I of course found that the upper one was much more rapidly affected by the sun than the lower one, and further that a thermometer placed deeper than the permanent one registered higher.

Freshly fallen snow is given in the text books as melting to one tenth of its bulk of water. I have not found quite as much with freshly fallen snow; but this very soon varies, partly in consequence of pressure, but chiefly through recrystallization, which takes place more rapidly as soon as the weather becomes a little warmer than usual. I have several times measured coarse-grained recrystallized snow, and found that it melts to one third of its bulk. This change of bulk often misleads people into thinking that a great deal has been melted, and two or three of our first rather warmer days caused the snow to sink down several inches without there being any melting. Nevertheless this change of condition is of course an important factor in the melting, as the quantity of snow which previously occupied a larger space comes now into contact with less air, and both the terrestrial heat and the solar can influence a greater weight of snow.

A reference to the curves for January and March will show that the temperature in the snow only slowly follows that of the air, so that occasionally the maximum of the air is below that of the snow, or the minimum above it.

Until the temperature in the snow at about the depth I measured reaches freezing point, we cannot speak of any real snow melting. The "snow melting" is often spoken of by the natives as a season, irrespective of there being any snow to melt; but this is a more gradual thing than is sometimes imagined. This year from about the beginning of March the sun cleared a few small patches on the northern slopes. These were several times covered with fresh snow, but soon cleared again. With the first of April the real snow melting began, and from the first of that month until the snow was away I always found the snow at the freezing point. The size of the bare patches was rapidly increased, and the water from the melting snow above ran on to them and was partly evaporated; but with the bright sun these patches, for some time swampy or muddy, gradually became drier. By the 12th the northern slopes were getting quite bared, but the flat places showed little change before May; and the southern slopes fairly commenced to be cleared about the 16th May.

If it were not that the increase in the amount of bared earth is so gradual I believe that this season of the year would be much more trying than is the case.

I made some further observations upon evaporation of ice in the shade, using the same tin (27 cm. by 22 centimetres × 5 cm.) as last year in Davos* hung up by wire in my screen. The total amount of evaporation for January was 9·1 mm., but as I made some alterations in my screen for other instruments I was unable to continue to weigh after that month.

The evaporation measured in my screen, from 9 a.m. to 3

* Preliminary Remarks on Observations made in Davos in the Winter 1881–82 by A. W. Waters, Proc. Manch. Lit. & Phil. Soc., 1882, p. 162.

p.m.; on February 7th, showed no loss.
„ 8th gain of 0·05.
„ 9th no loss.
„ 10th evaporation of 0·50 mm.
„ 12th „ 0·03.

This very inconsiderable loss through the day time arises partly from the temperature of the ice changing but slowly. Condensation producing gain on the 8th is very instructive, and such circumstances must be taken into consideration in studying the climate when the glaciers had a greater extension.

I also again filled a tin (painted white) with snow, and buried it as before in the snow so that the level of the snow in the tin was as near as possible the same as that surrounding it, and in this way we must find out very approximately the amount of evaporation from the surface of the snow covering the valley. It was placed in the sun and measured by weighing, and the weight lost is calculated out and expressed in the depth of water, which will mean, as we have seen, that at least three times this depth of snow has disappeared.

The results were:—

	Loss by evaporation from 9 a.m. to 3 p.m.		Temperature. 9 a.m.	Temperature. 1 p.m.	Temperature. 3 p.m.	Maximum. Solar radiation.	
Feb. 5th.—	0·07 mm.	(water)	−9·0 C.	−3·8 C.	−3·0 C.	37·4 C.	cloudless day, windy, moderately dry.
„ 23rd.—	0·60	do.	+3·4	+2·0	+2·0		fairly clear, windy, very dry.
„ 27th.—	0·27	do.	−3·4	+5·2	+4·8	43·6	nearly cloudless, little wind, very dry.
„ 28th.—	0·48	do.	+2·0	+2·6	+2·9	52·6	rather cloudy, windy, moderately dry.
Mar. 2nd.—	0·40	do.	−4·2	−1·1	−3·4	39·2	very little cloud, windy, very dry.
„ 5th.—	0·35	do.	−8·7	−0·8	+0·6	37·8	cloudless, moderate wind, moderately dry.
Apr. 2nd.—	0·27	do.	+2·1	+3·2	+1·9	51·6	rather cloudy, windy, moist.
„ 3rd.—	0·33	do.	+1·3	+5·7	+6·4	44·6	cloudless, very little wind, dry.
„ 4th.—	0·58	do.	+2·3	+7·9	+6·0	47·8	almost cloudless, little wind, dry.
„ 5th.—	0·43	do.	+2·6	+7·4	+8·0	44·8	cloudless, not very windy, dry.

The last two days cannot be looked upon as very exact, as the condition of the snow changed so much.

Besides these measurements made in the warmest part of the day I found the loss from—

Feb. 5th, 9 a.m. to Feb. 7th, 9 a.m. to be 0·16 mm.
„ 22nd, 3 p.m. to Feb. 23rd, 9 a.m. to be 0·28 mm.
„ 26th, 9 a.m. to Feb. 27th, 9 a.m. to be 0·67 mm.
„ 27th, 3 p.m. to Feb. 28th, 9 a.m. to be 0·48 mm.
April 3rd, 3 p.m. to April 4th, 9 a.m. to be 0·43 mm.
„ 4th, 3 p.m. to April 5th, 9 a.m. to be 0·62 mm.
„ 5th, 3 p.m. to April 6th, 9 a.m. to be 0·43 mm.

As the snow cannot be materially warmed the evaporation can never be very rapid from it, but this is quite different with the earth as soon as it is uncovered, as being dark it absorbs the heat and becomes very much warmed, causing rapid evaporation, so that where no fresh supplies of water are coming into the earth we may see it in a few days as dry as mummy dust. In order to see exactly how this takes place I propose next winter to bury a tin full of damp earth in earth of the same temperature and moisture.

I this winter made some preparatory observations by putting some very damp earth into my tin and burying it in the snow in the same way as I had done when it was full of snow, but as the tin was too large to weigh when full of earth I was only able to partly fill it, which would materially affect the exactness of the observation. The earth was, of course, kept cool by the snow, whereas if it had been surrounded by earth, it would have been warmed.

March 18th, added about 1 kilo water to about 4 kilos very dry earth; lost from 9 a.m. to 3 p.m. 1·06 mm. of water.

March 26th, lost from 9 a.m. to 3 p.m. 1·13 mm. of water.

I would specially call attention to the evaporation of the snow during the day time, on April 2nd and 3rd, both of which were days of genuine snow melting, and it will be seen that the amount of loss by evaporation was but small. This evidently depends upon the snow remaining at a lower temperature than the air.

This is a most important question, as one of the difficult problems with regard to these high climates, as health resorts, has always been what is to be done during the snow melting, and those patients and doctors who are not fully acquainted with the climate have not unnaturally rushed off with the idea that the melting of two or three feet of snow causes the air to be always laden with moisture. These experiments, as we expected, show however that the amount of moisture which passes into the air direct from the snow is but small, and that the bugbear of the snow-melting is much exaggerated. The meteorological figures taken for a number of years in several high stations show the months of March and April are among the driest of the year.

The experience of medical men and others who have lived for many years in these climates seems to be universal that the unpleasant and dangerous time is not, *per se*, when the snow is really melting, but as soon as the ground has become bare of snow, when people often experience feelings of cold and chilliness to which they have been quite unaccustomed during the cold weather of the winter, and therefore many who live in these places do not try to rush away at the first sign of snow melting, but rather towards the last.

Some of the days with the greatest snow melting were this year among the pleasantest of the winter, and from the 1st April to the 6th inclusive the average relative humidity or percentage of possible moisture was at 1 p.m. 55 per cent (calculated by Apjohn's formula), although the snow was rapidly melting all day, and two of these days were almost absolutely cloudless.

Although showing that there is not necessarily much dampness of the air connected with the snow melting I do not wish anyone to be misled into supposing that I am recommending this as a favourable time of year and that there are no disadvantages, for naturally the roads and villages are in a dirty and unpleasant condition, and in fact the roads have usually been dirty for a long time before the real snow melting begins. The early melting of the roads arises partly from the dirt on the roads, which absorbs the heat; but besides that, any snow which is pressed down sooner becomes soft than snow left as it fell. The reason of this we have seen to be that both the heat from the earth and the sun can sooner influence it. Besides the disadvantage of dirty roads, all the filth which has remained frozen during the winter has to be thawed.

Another point that must be taken into consideration is that the snow melting is not a thing which necessarily goes on steadily for a few days and is then finished, but, on the other hand, as the temperature has now risen and passes more frequently above and below freezing point, the weather becomes more unsettled, and during the month of March snow frequently falls—in fact, about as often as in any month of the year; and this also means that the sky is more clouded. Dr. Ludwig* gives the average cloudiness of the sky in the Oberengadine stations for ten years, and from his figures it seems that the cloudiness, which in January averages only 4·5 (scale 0—10), in February 4·6, increases in March to 5·3, and in April decreases to 4·8. Some figures which I have prepared from other high places fully bear this out. This is the opposite to what we find in the neighbourhood of London (Greenwich), for from some figures before me for a number of years we have January 7·6, February 7·9, March 6·4, April 5·9.

We have so far examined the snow as removed by the sun, but there are also occasionally times when a warm

* Das Oberengadin von Med. Dr. J. M. Ludwig. Stuttgart, 1877.

south wind keeps the air warm night and day, and melts the snow under unfavourable, cloudy, and oppressive conditions, but as I have not known any real snow melting of this kind during the last two years I am unable to give any particulars as regards this form of melting, which is however not so common.

As the conditions of the snow melting have been very imperfectly understood by the majority of English doctors, I am now trying to collect material for a more extended study of the question, but the few facts which I have mentioned support the views of many German and Swiss doctors of considerable practical experience, and will, I think, show that what must be done during the snow melting is a question to be decided upon the individual circumstances of each patient's case, always however remembering that the majority of those who have spent a winter in the cold of the high climates are when they go down to the damper air of the plain sensitive to the cold, and therefore it is better that they should not go to any place where spring weather has not fully set in, without being relaxing, and above all should avoid any place where the winter snow has not been melted away four or six weeks.

It is often incorrectly supposed that any one who has been able to bear the extreme cold of a winter in the high climates will not feel the more moderate cold of a lower station.

Wind.

I had last year (loc. cit. p. 179) to express my regret that I could not find a position for my anemometer, which was quite satisfactory to me, and I have to say the same thing again now. As the hotel is more or less on the side of a hill and near the highest part of the road, it was most difficult to find a spot which was not sheltered by some building, and in consequence I had to place my instrument on a small mound where I think we may say it received no shelter, although I have a few times seen a little more wind on the S.E. of the hotel and also on the further rink, etc. My object has been as far as possible to register the amount of wind to which patients are exposed, and therefore, my regret at having to place it on a mound, as undoubtedly there was more wind at the top than on the level. The position was between the hotel and the main road, so that in going to the skating rink, or for a walk in any direction, it was necessary to pass close by it. It also overlooked the tennis court, causing me some anxiety lest the balls should damage any of the instruments on the mound. It will be seen that if it could have been three feet lower the position would have been a very good one.

It would not be fair if I did not point out that the winter of 1881—1882 was an exceptionally still one generally, whereas this winter has not been as favourable in that respect.

This, however, has not been an especially windy winter, which I was able to gather from the opinion of uninterested parties; and to prove this I give a comparison of the wind taken this winter at Sils Maria, a village 7 miles S.W., and at Bevers, 4 miles N.E. of St. Moritz, and also of Davos Platz, in a parallel valley.

The averages for St. Moritz are for 4—7 years, and include all the observations made; for the other places they are from all the material which happened to be available here. The figures are given in percentage of times that the Swiss anemometer was not moved. This is here wrongly called "windstille."

	Oct.	Nov.	Dec.		Jan.	Feb.	Mar.
Sils Maria (average of 7—8 years)...	63	57	61	......	60	62	61
1882..................	—	76	77	1883...	56	63	52
Bevers (average of 9—11 years)......	57	59	68	......	66	56	44
1882..................	67	58	73	1883...	70	51	41

	Oct.	Nov.	Dec.		Jan.	Feb.	Mar.
Davos (average of 8—10 years) ...	63 ...	71 ...	74	......	71 ...	59 ...	51
1882..................	83 ...	76 ...	88	1883...	81 ...	69 ...	74
St. Moritz average..	52 ...	53 ...	53	......	57 ...	45 ...	41

Since the Swiss anemometer in St. Moritz (which however indicated the greatest average amount of wind) was in a very sheltered position, the figures obtained by it cannot be directly compared with those of the neighbouring places.

The number of miles of wind registered in

November 1882, was ....1965·33
December ....1422·74
January 1883 ....1674·94
February....................................1556·72
March ....2740·75
April ....2181·05

The following analysis will give an idea as to the frequency of strong wind, and by the side of the two months in St. Moritz I give a similar table for the month of January, 1882, in Davos. That month was among the stillest which has ever been known in the Alps.

The "night" is from 3 p.m. of the previous day to 9 a.m., "morning" 9 a.m. to 1 p.m., "afternoon" 1 p.m. to 3 p.m.

Average rate per hour.

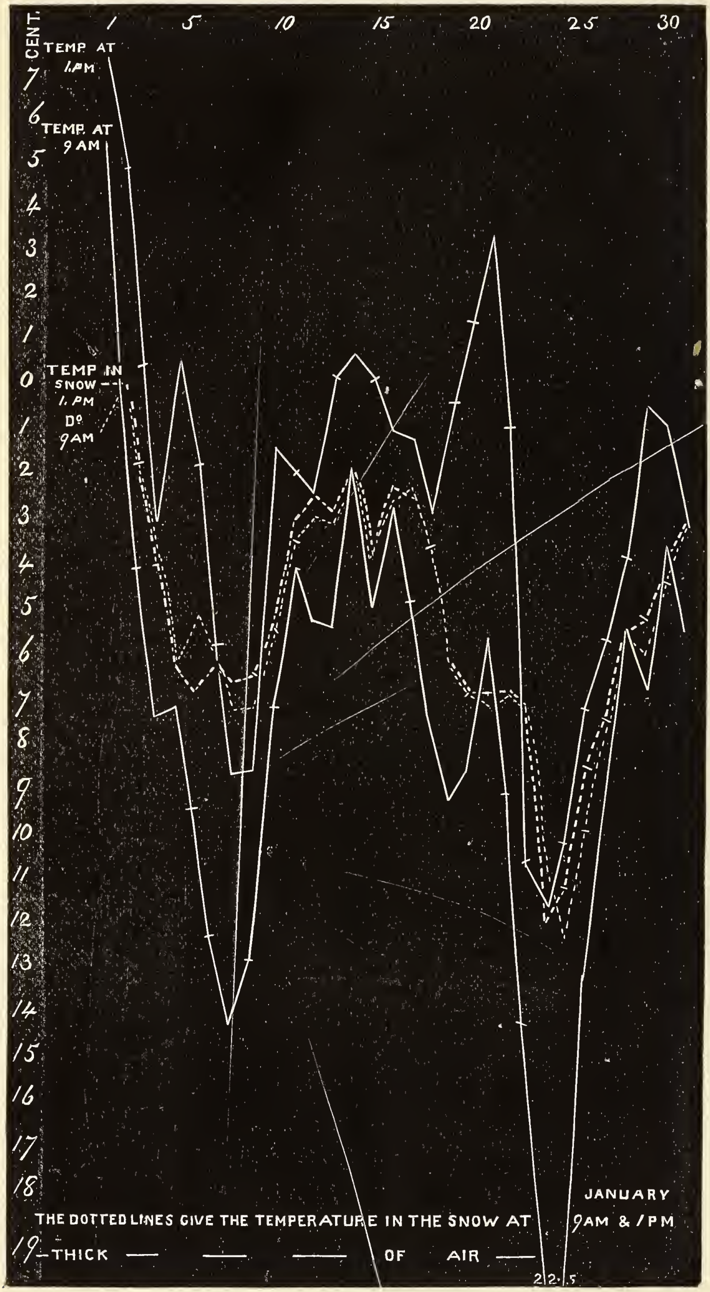
	January, 1882. Davos Platz.			January, 1883. St. Moritz.			March, 1883. St. Moritz.		
	Night. 3 p.m. to 9 a.m. Times	Morning 9 a.m. to 1 p.m. Times	Aftern. 1 p.m. to 3 p.m. Times	Night 3 p.m. to 9 a.m. Times	Morn. 9 a.m. to 1 p.m. Times	After. 1 p.m. to 3 p.m. Times	Night 3 p.m. to 9 a.m. Times	Morn. 9 a.m. to 1 p.m. Times	After. 1 p.m. to 3 p.m. Times
No movement....	15	3	3	0	0	0	0	0	0
Less than 0·5 m.	12	14	23	1	4	2	2	1	0
Between 0·5 & 1 m.	2	4	3	9	6	7	4	1	1
,, 1 & 2 m.	1	5	1	12	9	7	8	3	1
,, 2 & 4 m.	...	2	0	7	5	6	9	9	7
,, 4 & 6 m.	1	2	1	2	5	4	5	6	3
,, 6 & 10 m.	...	...	...	...	1	2	3	7	7
,, 10 & 15 m.	...	...	...	...	1	3	...	3	9
Over 15 m.	...	...	...	...	...	...	...	...	2

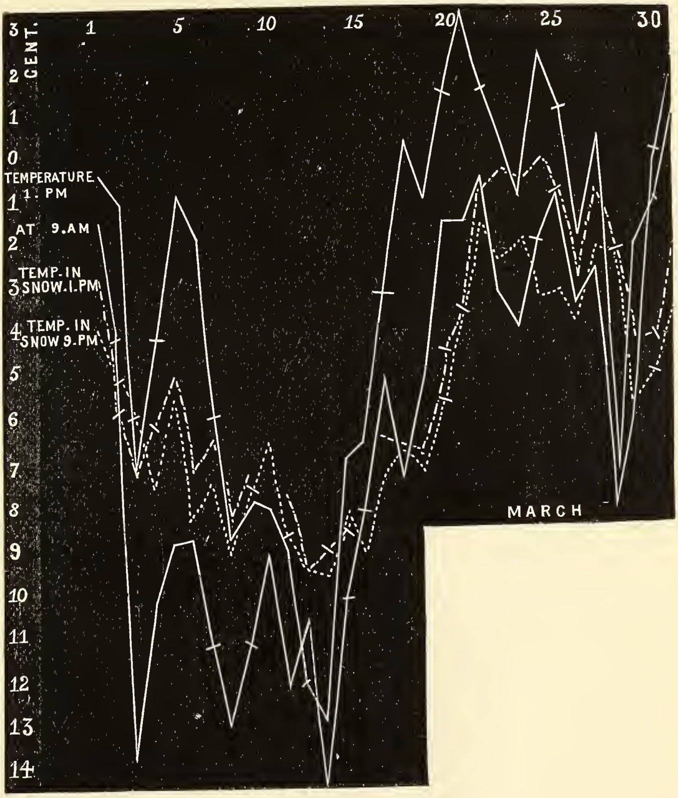
I do not think that in real winter weather we can consider any day as perfect when the rate is above 1 mile an hour. This amount of movement would hardly be felt in warm weather, but with a very low temperature is more trying. It is hardly necessary to remind meteorologists that if the instrument had been placed on the top of a house the amount registered would have been very much larger than was the case.

Some observations made for the Swiss Meteorological Society have been published to show that St. Moritz is in the winter months warmer than Davos. It seemed strange that St. Moritz, which is nearly 1,000 feet higher, should nearly always average warmer. However, as the observations made by Messrs. Townsend and Greathead between 1868 and 1871* give a lower temperature, and as mine,† taken this winter on the same spot as Mr. Greathead's show St. Moritz decidedly colder than Davos, I tried to find out the reason of the results to which I referred, differing from those obtained by Messrs. Townsend, Greathead, and myself. Mr. Schmidt, who formerly took the observations, very kindly gave me every assistance in trying to find out the cause of this discrepancy, and on two occasions took the temperature for about a week at 1 p.m., in order that I might compare with mine. His house is lower down in the village, and is probably slightly warmer than the Kulm hotel; but the mean difference from the 22nd to the 29th

* Klimatotherapie von Dr. Hermann Weber, p. 156, aus Ziemssen's Allgemeine Therapie, vol. ii. pt. 1.

† A comparison with the Davos official observations taken in the Swiss way, as published in the local paper, shows that at one p.m. in January this year, Davos was about 2° Cent., and in March about $3\frac{1}{2}$° Cent. warmer than St. Moritz; and further comparisons show that I have obtained much the lower figures throughout the winter. The temperature here was, at 9 a.m. in November, $-3{\cdot}4$° Cent., and at 9 a.m. in December, $-6{\cdot}06$° Cent.


CENT.
TEMP. AT 1.PM
TEMP. AT 9 AM
TEMP IN SNOW 1. PM
Dº 9AM
1 5 10 15 20 25 30
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
JANUARY
THE DOTTED LINES GIVE THE TEMPERATURE IN THE SNOW AT 9AM & 1PM
THICK — — — OF AIR —
22.5



CENT.
1
5
10
15
20
25
30
3
2
1
0
TEMPERATURE
1. PM
1
AT 9.AM
2
TEMP. IN
SNOW. I. PM
3
TEMP. IN
SNOW 9. PM
4
5
6
7
8
9
10
11
12
13
14
MARCH

of January being 2·5° Cent. (4·5° F.), and March 11th to 20th 2·9° Cent. (5·2° F.) warmer than mine, it would seem that the difference principally arises from different screening and placing of the instruments. The screen-box is so placed in a corner that it will receive reflected heat from two walls and probably the readings are too high on that account.

As I pointed out last year, the question of screening is most difficult in such a climate, and therefore I was very glad towards the end of the season to accept from Dr. Berry the loan of one of the Swiss metal cylinder-screens, which was 50 centim. high and 25 centim. in diameter.

These are usually placed just outside an upper window and the figures to which I have referred were so taken. I however placed it with a board below, as sometimes used by the Swiss, and put this on a stand near to my own screen. I then placed the lid of a large box about half a metre away in a sloping position to the south of the thermometer cylinder. This formed a shading roof and roughly made a protection similar to that recommended by Professor Wild.

The metal screen was entirely in the shade from 9.30 and but little sun shone on it before that, so that the one o'clock observation would be uninfluenced by the sun. The next question is at what height should the thermometer be placed. I take it that one of the objects of the screen is to prevent terrestial radiation from the thermometer, and that therefore the thermometer should be well protected by the cylinder, but having seen the thermometer at the lower level of the cylinder in one of the Swiss stations, I placed one thermometer about one inch below the level of the cylinder so that it would be always kept in shade by it but be able to radiate out heat; another one I placed near the middle, so that it would receive any heat from the metal if it was warmer than the air.

The upper thermometer which, as explained, was fully protected, was, taking the mean of 16 days, 1·28 Fahr. warmer than the lower one, sometimes the difference being very considerable. The lower thermometer with the bulb below the level of the screen gave mean readings 0·4 Fahr. colder than my screen, while the one in the middle of the metal screen gave 0·9 Fahr. warmer than in my wooden one.

I also for comparison frequently hung my alcohol minimum thermometer on the north side of my wooden screen so that it was always in the shade, and this gave on an average for 25 days a temperature of 1·7 Fahr. warmer than inside the box. I consider that much of the difference must be attributed to heat reflected from the snow. On one occasion when it was 5·7 Fahr. higher than inside I swung it for a few minutes, by which it was reduced until the two closely approximated.

The screen which I used was large and specially adapted for the evaporation experiments I proposed making. The inner one was the box I used last year, 90 cm. wide by 75 cm. by 60 cm. high (see loc. cit. p. 162), but as I unfortunately had no pavilion shade this year, I had to cover it with another louvre screen and left a space of about 25 centimetres all round between these two louvre boxes. I still think that this construction is not unsuitable for such a climate as this, although with so much wood the thermometers will not indicate changes quite as rapidly as should be the case, and further, I am very doubtful about the Stevensen screen being suitable, but as the question of screening is so important and as the conditions are so different from those which obtain in England, I purpose making some exact comparisons of different methods, as perhaps some of the figures showing most variation may have arisen from the screening being only of a provisional character, and I do not think that the Swiss metal screen ought to have a board at such a short distance below the thermometers. No doubt when the ground is covered with snow the height at which the instruments are placed above it will cause differences.

Unless the instruments are satisfactorily placed, the observations with regard to moisture will be utterly unreliable.

The 9 p.m. temperature observations and also the one at 1 p.m. on the 10th of March, were taken from my rooms by means of an electrical arrangement which I have devised, and of which I have sent a fuller description to another Society, but I may say that the thermometer is a spiral metal thermometer which carries a finger. This thermometer was kept in the screen with the other instruments. I made the scale with a number of wires here uncovered, but elsewhere insulated, wound over a piece of ebonite, and the finger of the instrument is brought down upon these wires by two electro-magnets, and in my room, by a simple contrivance, I am able to tell which wire is touched by the finger. I have also arranged a hair hygrometer to work in the same way, and intended to have both instruments working this winter, but through delays in getting the necessary material, and other causes, the winter caught me up, and when the weather was cold I was obliged to give up the idea of making changes.* Consequently I used the thermometer, although being short of wire I only completed the scale to —11 Cent., which is the reason why on many nights when the temperature fell below this I am unable to give any figures.

The instrument which has been used many hundreds of times has turned out quite satisfactory, and I am sure that the principle can be applied to almost every instrument that carries a finger. The part of the hygrometer moved by the hair, for which I paid a long price to an incompetent

* The instrument is only divided into $\frac{1}{3}$ of a degree Centigrade, but I purpose making another in a few weeks divided to $\frac{1}{10}$ of a degree.

Zürich firm, was however so unsatisfactorily made that I decided not to trouble about that instrument until I could myself go to the town where it was manufactured and get some changes made.

The temperature one inch above the snow was taken with a minimum alcohol thermometer, and this is approximately terrestial radiation.

The solar radiation thermometer was only put up temporarily, and was fastened with string to the large wire netting with which I was obliged to protect my anemometer from the children.

	TEMPERATURE IN SHADE.							Minimum.	TEMPERATURE OF SNOW.			WIND.									Evaporation.	Min. temp. 1in. above snow.	Solar radiation.	CLOUDS. (0–10).		
												Rate in miles per hour.			Direction											
															Below.			By Clouds.								
	9 a.m.		1 p.m.		3 p.m.		9 p.m.		9 a.m.	1 p.m.	3 p.m.	9 a.m. from 3 p.m.	1 p.m. from 9 a.m.	3 p.m. from 1 p.m.	9 a.m.	1 p.m	3 p.m.	9 a.m.	1 p.m.	3 p.m.				9 a.m.	1 p.m.	3 p.m.
	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Cent.	Cent.										mm.	Fahr.	Cent.			
1..	+5·5	(41·9)	+7·3	(45·1)	+5·9	(42·6)	+3·3	32·1	−1·1	0	0	1·56	4·16	1·81	NE	N	W	W	W	NW	0·28	29		7	5	6
2..	−0·6	(30·9)	+4·8	(40·6)	+4·1	(39·4)	−0·3	28·6	0	0	0	1·11	0·52	5·14	SW	N	SW	S	SW	SW	0·30	19		7	7	10
3..	−4·2	(24·4)	−0 4	(31·3)	−1·3	(29·7)	−3·0	21·3	−1·7	−1·7	−2·5	1·70	1·25	1·73	E	W	W	W	SW	W	} 1·46	9·5		8	9	7
4..	−7·4	(18·7)	−3·0	(26·6)	−3·0	(26·6)	−8·6	17·7	−3·7	−4·0	−4·2	3·03	0·90	2·20	N	N	E				}	9·0		0	0	0
5..	−7·2	(19·0)	+0·6	(33·1)	+2·1	(35·8)	−4·0	17·9	−6·2	−6·2	−5·2	0·57	0·47	0·62	NE	NW	NW		NW	W	0·22	0		0·5	0	4
6..	−9·4	(15·1)	−1·7	(28·9)	−4·0	(24·8)	−7·6	13·9	−5·2	−6·7	−6·0	0·46	1·35	0·52	N	SE	W	N	NNW	W	0·40	−1		0	0·4	0·5
7..	−12·3	(9·9)	−5 8	(21·6)	−5·7	(21·7)		7·4	−6·1	−6·2	−6·1	1·26	0·53	1·93	NE	E	W	N		N	0·22	−2		0·5	0·5	0·5
8..	−14·2	(6·5)	−8·6	(16·5)	−8·9	(16·0)		6·5	−7·3	−6·5	−6·5	0·70	0·54	1·06	NE	NE	N	SE	E		0·05	−7		5	9 5	8·5
9..	−12·7	(9·1)	−8·5	(16·7)	−7·8	(18·0)		6·9	−7·2	−6·4	−6·2	1·06	2·77	5·65	W	S	SW	NW	SW	WSW	0·10	0		0·3	9	5·0
10..	−7·2	(19·0)	−1·3	(29·7)	−1·5	(29·3)		11·4	−5·4	−5·2	−5·2	1·27	0·92	0·69	NE	E	SE				0·05	+1		10	9·5	10
11..	−4·0	(24·8)	−1·8	(28·8)	−2·8	(27·0)		22·3	−3·5	−3·0	−3·0	0·52	1·65	6·21		SW	S				0·18	11		10	10	10
12..	−5·3	(22·5)	−2·5	(27·5)	−2·7	(27·1)		18·8	−2·9	−2·5	−2·5	3·82	2·32	3·83	SW	WSW	SW	S	SW	S	0·17	8		7	8·0	8
13..	−5·4	(22·3)	+0·3	(32·5)	0·0	(32·0)	0	18·8	−3·1	−2·7	−2·5	1·48	1·98	3·61	S	NW	NW				0·18	11		10	10	10
14..	−1·8	(28·8)	+0·7	(33·3)	+1·0	(33·8)	−4·3	27·7	−1·9	−1·9	−1·9	2·38	0·39	1·17	W	W	NE			SE	0·15	20		6	1	1
15..	−4·8	(23·4)	+0·3	(32·5)	+0·2	(32·4)	−1·6	11·4	−3·9	−3·9		1·48	1·75	2·06	SW	W	E	SE	SE	W	0·23	1		8	5	4
16..	−2·6	(27·3)	−1·0	(30·2)	−0·3	(31·5)	−2·6	16·4	−2·5	−2·3	−2·1	0·61	1·90	0·50	N	NE	W				0·10			10	10	10
17..	−4·7	(23·5)	−1·2	(29·8)	−1·4	(29·5)		22·1	−2·2	−2·4	−2·4	0·67	0·89	1·12	NE	NE	NW	NE		N	0·10			8	8	7
18..	−7·2	(19·0)	−2·8	(27·0)	−3·2	(26·2)	−7·0	15·6	−3·5	—	−2·5	0·75	1·88	1·26	NE	E	NE				0·10			9	0	0
19..	−9·2	(15·4)	−0·4	(31·3)	0	(32·0)	−7·3	13·4	−6·2	−6·2	−4·9	0·95	0·39	0·37	NE	E	NE		N		0·20	−3		1	1·5	0·1
20..	−8·5	(16·7)	+1·4	(34·5)	+0·8	(33·4)	−4·0	12·4	−6·7	−6·7	−6·2	0·68	1·23	0·29	NE	NE	W					−6		0	0·5	6·
21..	−5·4	(22·3)	+3·4	(38·1)	+3·3	(37·9)	−4·6	18·8	−7·1	−6·7	−6·2	0·66	1·03	0·77	NE	NW	NE					0		0·8	0·5	0·2
22..	−9·0	(15·8)	−0·8	(30·6)	−1·0	(30·2)	−6·0	11·1	−6·7	−6·7	−6·2	1·15	3·48	0·82	E	NE	N			N		−4	35	0	0·1	0 5
23..	−14·2	(6·4)	−10·6	(12·9)	−11·0	(12·2)		2·6	−7·2	−7·2	−7·7	3·46	3·44	4·78	NE	E	NE		N	N			27	0·1	1·0	0·5
24..	−18·2	(−0·8)	−11·5	(11·3)	−12·3	(9·9)		−0·8	−10·5	−11·7		1·57	3·09	3·71	E	W	N	W						0·2	0·	0·5
25..	−22·5	(−8·5)	−10·2	(13·6)	−10·8	(12·6)		−11·3	−12·2	−11·2	−11 0	2·42	0·41	0·84	ESE	SE	N	W		NW			28·8	0	0·5	3·
26..	−13·0	(+8·6)	−7·2	(19·0)	−6·7	(19·9)		+1·9	−9·7	−8·5	−8·4	1·15	4·76	10·85	N	SW	S		W	SW			31·6	5	9·5	6
27..	−9·2	(15·5)	−5·6	(21·9)	−7·2	(19·0)		+6·7	−7·5	−7·4	−7·1	1·61	4·28	3 04	W	S	W		NW	NW		−3·	30·8	10	7	6
28..	−5·4	(22·3)	−3·7	(25·3)	−4·2	(24·4)	−8·0	12·8	−5·5	−5·4	−5·2	5·44	4·96	4·81	E	N	W	SW	NW	NW		+2	38·4	8	7	8
29..	−6·6	(20·1)	−0·4	(31·3)	−0·4	(31·3)	−6·0	10·9	−5·9	−5·2	−4·7	2·35	7·71	13·40	SW	S	S		NW	WNW		−2	37·4	7	8	8
30..	−3·4	(25·9)	−0·8	(30·6)	−1·2	(29·8)	−2·6	18·8	−4·4	−3·7	−3·5	7·07	13·01	10·53	SW	SW	SW		S	S		+7	33·6	9	7	7
31..	−5·4	(22·3)	−3·2	(26·2)	−2·2	(28·0)	−4·0	20·8	−2·9	−2·9	−2·8	3·67	4·35	9·00	NE	SW	SW			S			21·8	9	10	9
	−7·6		−2·4		−2·6			13·73	5·15	−5·01	−4·58	1·82	2·52	3·36							9·10			5·0	5·0	5·0

	TEMPERATURE IN SHADE.							Minimum.	TEMPERATURE OF SNOW.			WIND.									Min. Temp. 1in. above the snow.	Solar Radiation.	CLOUDS. (0–10)		
												Rate in miles per hour,			Direction.										
															Below.			By clouds.							
	9 a.m.		1 p.m.		3 p.m.		9 p.m.		9 a.m.	1 p.m.	3 p.m.	9 a.m. from 3 p.m.	1 p.m. from 9 a.m.	3 p.m. from 1 p.m.	9 a.m.	1 p.m.	3 p.m.	9 a.m.	1 p.m.	3 p.m.			9 a.m.	1 p.m.	3 p.m.
	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Cent.	Cent.										Fahr.	Cent.			
1....	−1·6	(29·1)	−0·4	(31·3)	0	(32·0)	−4·3	24·6	−3·9	−2·9	−2·3	1·70	2·33	2·23	NE	N	NE	NW			14	24·4	8	10	9·5
2....	−4·2	(24·4)	−1·1	(30·0)	−3·4	(25·9)	−10·3	12·5	−5·1	−4·7	−4·4	1·46	4·00	6.98	N	N	SW			NE	3	39·2	0·1	0·1	1
3....	−13·5	(7·7)	−7·1	(19·2)	−6·2	(20·8)	−10·0	−0·5	−5·8	−7·3		1·38	6·89	10·72	NE	N	N		NE			34·2	0	0	0·1
4....	−10·2	(13·6)	−4·2	(24·4)	−3·1	(26·4)	−8·6	+3·0	−7·5	−6·2	−5·5	4·83	8·24	12·99	N	N	N	N				35·2	0	0	0·1
5....	−8·7	(16·4)	−0·8	(30·6)	+0·6	(33·1)	−6·3	5·7	−5·4	−5·0	−3·4	1·96	3·16	1·70	NE	N	NE				−5	37·8	0	0	0
6....	−8·6	(16·5)	−1·7	(28·9)	−5·0	(23·0)	−5·6	8·5	−8·1	−7·1	−6·9	1·04	6·48	6·23	E	W	W		SW			39·2	3	9·5	10
7....	−11·2	(11·8)	−5·8	(21·6)	−7·5	(18·5)		5·7	−7·5	−6·4	−6·3	1·89	1·32	4·09	NE	E	N	N	N	N	−4	35·7	8	6	7
8....	−12·7	(9·1)	−8·7	(16·3)	−9·1	(15·6)		−1·6	−9·0	−8·4	−7·5	0·56	2·26	3·23	N	NE	NE					25·7	9·5	10	9·5
9....	−11·0	(12·2)	−7·7	(18·1)	−7·7	(18·1)	−9·3	+6·9	−7·5	−7·2	−6·7	2·09	4·23	7·08	NE	N	N				+5	23·8	10	10	10
10....	−9·2	(15·4)	−8·0ˣ	(17·6)	−8·0	(17·6)		11·5	−6·5		−6·1	8·10			NE		SW					25·8	10	10	9·5
11....	−12·0	(10·4)	−8·9	(16·0)	−8·9	(16·0)		−3·6	−8·5	−7·7	−7·2	0·70	1·56	2·75	N	NE	SW		N	NW		35·0	7	5	7
12....	−10·6	(12·9)	−11·8	(10·8)	−12·6	(9·3)		−3·7	−9·4	−9·4	−9·4	0·76	4·78	4·74	S	NE	N					13·0	10	10	10
13....	−14·4	(6·1)	−12·7	(9·2)	−13·0	(8·6)		−1·0	−9·5	−8·9	−8·7	5·93	3·55	3·82	S	SW	S	NE			0	29·8	5	10	10
14....	−10·0	(14·0)	−6·8	(19·8)	−7·0	(19·4)		+6·8	−8·1	−8·4	−7·5	2·57	6·29	9·36	SW	W	W	WNW	WNW	W		39·0	7	2	3
15....	−8·0	(17·6)	−6·5	(20·3)	−5·7	(21·7)	−8·3	+4·0	−8·9		−8·1	5·45	14·88	13·80	W	W	W	SW	SW	SW	−6	44·8	2	6	2
16....	−5·0	(23·0)	−3·2	(26·2)	−4·3	(24·3)		13·2	−7·3	−6·3	−5·6	5·34	10·68	13·99	S	SW	S	S	SW	SW	+10·5	43·6	7	5	4
17....	−7·4	(18·7)	+0·4	(32·7)	+0·2	(32·4)		9·8	−6·5	−6·4	−2·7	2·88	2·25	4·84	N	NE	SW				0	42·4	3	4	1
18....	−5·0	(23·0)	−0·9	(30·4)	−0·4	(31·3)		8·5	−7·2	−6·7	−5·9	1·79	7·33	10·82	SW	SW	SW		SSW	SW	−3	43·4	2	1·5	4
19....	−1·4	(29·5)	+1·4	(34·5)	+0·3	(32·5)	−2·6	18·0	−5·5	−4·4	−3·9	2·46	0·92	3·55	SW	N	SW	SW			+11	37·6	8	10	10
20....	−1·4	(29·5)	+3·3	(37·9)	+2·4	(36·3)	−1·3	17·5	−3·4	−3·4	−0·0	0·47	1·35	0·91	N	N	S				11	50·4	2	9·5	10
21....	−0·4	(31·3)	+1·5	(34·7)	+0·6	(33·1)	−1·6	25·5	−1·5	−0·7	−1·0	0·39	2·26	9·92	N	SW	SW	S	SW	SW	23	38·7	9·5	9	9·5
22....	−3·2	(26·2)	+0·4	(32·7)	+0·5	(32·9)	−5·6	18·5	−2·4	−0·3	−0·0	3·97	2·50	3·37	N	S	N	S			11	38·8	9	10	10
23....	−3·8	(25·2)	−0·8	(30·6)	−4·4	(24·1)	−7·3	15·5	−1·9	−0·5	−0·0	2·16	4·28	15·05	W	SW	SW				16	46·4	10	6	10
24....	−1·8	(28·8)	+2·3	(36·1)	+2·6	(36·7)	−2·0	13·5	−3·2	−0·0	−0·0	2·84	0·16	6·83	N	NE	WSW	N	NW		7	48·8	8	9·5	8
25....	−0·8	(30·6)	+1·2	(34·2)	+0·7	(33·3)	−5·6	14·0	−3·0	−0·7	−3·0	1·27	4·14	10·62	E	W	SW				5	42·8	0·2	0·1	0
26....	−3·4	(25·9)	−1·7	(28·9)	−1·4	(29·5)	−3·0	20·5	−3·7	−2·9	−2·6	7·07	11·15	12·14	S	SW	S					32·2	10	10	10
27....	−2·4	(27·7)	+0·6	(33·1)	−2·5	(27·5)	−5·6	23·5	−2·1	−0·8	−0·0	8·89	2·27	17·78	W	W	W					53·8	9·5	2·0	7
28....	−7·8	(18·0)	−7·0	(19·4)	−6·8	(19·8)	−3·6	10·0	−2·1	−2·1	−1·8	3·85	7·29	6·88	E	E	NE	NW	N	NW		36·8	9	9·8	9·5
29....	−5·8	(21·6)	−2·0	(28·4)	−1·7	(28·9)	−9·0	8·5	−5·6	−4·1	−2·6	2·55	2·27	3·89	N	SW	N	NW	NW		0	41·6	4	0·1	0
30....	+0·2	(32·4)	−1·0	(30·2)	−1·8	(28·8)	−4·6	9·5	−4·9	−4·0	−1·5	0·55	7·42	11·47	W	SW	SW	W	SW	SW	−1	44·6	3	8	9
31....	+2·2	(36·0)	+1·2	(34·2)	+0·3	(32·5)	−2·0	16·0	−3·5	−2·0	−2·2	4·04	4·74	11·60	NE	SW	SW					44·2	0·1	3	9·5
	−6·23		−3·11		−3·62			9·98	−5·63	−4·45	−4·09	2·90	4·69	7·77								37·7	5·6	6·0	6·4

MICROSCOPICAL AND NATURAL HISTORY SECTION.

Ordinary Meeting, 12th March, 1883.

ALFRED BROTHERS, F.R.A.S., Vice-President of the Society, in the Chair.

Mr. Francis Nicholson, F.L.S., of Fountain Street, Manchester, was elected a member of the Section.

Mr. THOMAS ROGERS exhibited a section, prepared and mounted by Mr. H. Hensoldt, of a meteorite found at Braunfels in Germany, in which were fluid cavities stated to show under certain circumstances a slight movement of the contents.

Mr. JOHN BOYD read some notes on the male of Argulus Foliaceus, a parasite found on the Carp, and exhibited living specimens and diagrams illustrative of the anatomy of this Entomostracan. He drew special attention to the inaccuracy of Jurine's description of the male organs of generation, viz.: a penis on the last swimming leg on each side and seminal vesicles on the corresponding joints of the preceding pair of legs, and showed that the supposed penis was a thumblike hook, and that each of the so-called seminal vesicles contained a recess with a flap, into which the corresponding thumb could be hooked. After commenting on the extreme improbability of the generative organ being doubled, as Jurine supposed, Mr. Boyd pointed out that the organs in question were evidently claspers used to seize and hold the female, just as the last pair of legs in Diaptomus is used, and showed by a diagram that in that animal one leg of the last pair is abnormally enlarged and furnished with a hinged joint to enable it to grasp. Mr. Boyd then explained that the real penis of Argulus was to be found in the usual position, viz.: between the last pair of legs.

On the motion of Mr. C. BAILEY, it was resolved that Mr. Boyd's communication be recommended to the parent Society for publication in the Memoirs.

Annual Meeting, April 9th, 1883.

J. COSMO MELVILL, M.A., F.L.S., President of the Section, in the Chair.

The Minutes of the last Meeting were read and confirmed.

Mr. Henry Hoyle Howorth, F.S.A., of Derby House, Eccles, and 8, St. James's Square, Manchester, Barrister-at-Law, was elected a member of the Section.

The Honorary Secretary's Report and the Honorary Treasurer's Report and Accounts of the Session were presented and read by the Honorary Treasurer, and after slight alteration and the insertion of Dr. Alcock's second paper on the Development of the Frog, read at the Annual Meeting, 1882, in the former.

On the motion of Mr. J. BOYD, seconded by Dr. TATHAM, it was resolved that they be received, adopted, and printed.

The PRESIDENT informed the meeting that the Council recommended the abandonment for the present of the proposed dredging excursion.

The following were elected officers for the ensuing Session 1883-4:—

President:

J. COSMO MELVILL, M.A., F.L.S.

Vice-Presidents:

A. BROTHERS, F.R.A.S.
R. D. DARBISHIRE, F.G.S.
PROF. W. BOYD DAWKINS, F.R.S., F.G.S.

Treasurer:

MARK STIRRUP, F.G.S.

Secretary:

ROBT. E. CUNLIFFE.

Council:

THOS. ALCOCK, M.D.
CHAS. BAILEY, F.L.S.
WALTER E. BARRATT.
J. BOYD.
A. MILNES MARSHALL, F.L.S.
THOS. ROGERS.
J. F. W. TATHAM, M.D.
W. C. WILLIAMSON, F.R.S.

Secretary's Report of the Session 1882-3 of the Microscopical and Natural History Section of the Manchester Literary and Philosophical Society:

During the session the Section has met seven times, and the Council four times. The average attendance has been 11.

Our numbers have decreased during the year. Last session we had 32 Members and 13 Associates. Of these we have lost by death our valued colleague Mr. H. A. Hurst, and our Assistant Librarian Mr. B. B. Labrey, and Messrs. E. W. Nix and J. Plant have resigned, whilst Mr. F. Nicholson has been elected, leaving to-day 31 Members and 11 Associates.

There have been 19 communications to the Section as against 23 last session. Of these Prof. Williamson's "On the present state of the knowledge of the relations between Lepidodendron, Sigillaria, and Stigmaria," Mr. R. D. Darbishire and Prof. A. M. Marshall's "On their dredging excursion at Oban," Dr. Alcock's "On the structure of the shell of several species of Polymorphina," and Mr. John Boyd's "On the male of Argulus Foliaceus," are of special importance, and the last two have been recommended to the parent Society for publication in the Memoirs. The concluding portion of Dr. Alcock's paper on the Development of the Tadpole, read at the Annual Meeting in April, 1882, has also been recommended for publication.

The Sectional meeting announced for the 4th of December was postponed, and, on the invitation of the parent Society, held jointly with their meeting on the 12th of that month, and the parent Society were invited to take part in our meeting on the 15th of January.

In November a temporary arrangement was sanctioned enabling the authors of communications to our meetings to have a brief note of their papers published promptly in certain local and scientific papers; but the privilege has only once been exercised.

In consequence of there being no distinction in the library receiving book between books acquired by the Section and those acquired by the parent Society, I am unable to report the additions made by the Section to our library.

I would again venture to draw attention to the desirability of members making communications supplying the Secretary promptly with an epitome of each paper for entry on the minutes.

A sub-committee was in January appointed to arrange, and invitations have been sent to our Members and Associates to take part in, a dredging expedition; but there has not been a sufficient response to justify its being carried out.

6th April, 1883.

THE MICROSCOPICAL AND NATURAL HISTORY SECTION OF THE LITERARY AND PHILOSOPHICAL SOCIETY OF MANCHESTER IN ACCOUNT WITH MARK STIRRUP, TREASURER.

Dr.

			£	s.	d.
1882.					
Oct. 31.	To	Thos. J. Day, Challenger Reports	6	10	0
„ 31.	„	Jas. E. Cornish, Microscopical Journal, Jan. 3rd, to July......	1	2	6
Nov. 3.	„	Jas. Collins & Co., Envelopes	0	7	6
„ 13.	„	H. T. Stainton, Zoological Record	1	0	0
1883.					
Feb. 15.	„	J. Van Voorst, Ibis for 1883	1	1	0
„ 17.	„	Jas. E. Cornish, Microscopical Journal, Oct. to Jan. 3rd	0	14	7
Mar. 9.	„	Thos. J. Day, Challenger Reports, Vol. vi.	2	2	0
„ 9.	„	Parent Society	2	2	0
„ 16.	„	Wm. Roscoe, Postage, &c. 22s. 1d., Tea, Coffee, &c. £3 6s. 8d. ...	4	8	9
„ 27.	„	Chas. Simms & Co., Circulars and Cards	3	9	6
	„	Balance in Manchester and Salford Bank, St. Ann's-street	119	19	9
			£142	17	7

Cr.

			£	s.	d.
1882.					
April	By	Balance in Manchester and Salford Bank, St. Ann's-street Branch...	117	1	0
1882-3	„	Subscriptions for Year and Arrears	23	10	0
1882.					
Dec. 20.	„	Interest allowed by Bank	2	6	7
			£142	17	7

Examined and found correct,
March 29th, 1883.

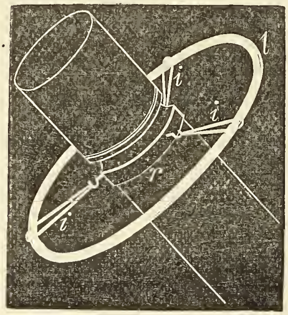
(Signed) WALTER E. BARRATT.
THOMAS ROGERS.

PHYSICAL AND MATHEMATICAL SECTION.

January 16th, 1883.

Joseph Baxendell, F.R.A.S., President of the Section, in the Chair.

Dr. J. P. Joule, F.R.S., exhibited and explained an arrangement for damping the small oscillations of a telescope.



The figure represents the object glass end of a telescope armed with the leaden ring *l*. A circle of brass, *r*, girding the tube, carries hooks which hold the caoutchouc bands *i*, *i*, *i*, thrown over the leaden ring. A similarly supported leaden ring is placed at the eyepiece end. I have applied rings weighing together 8lbs. to a telescope tube weighing 13lbs. with the result that when wind was blowing the small oscillations were so far subdued that very satisfactory definition of the object was obtained, which without the rings would have been impossible.

Annual Meeting March 13th, 1883.

JOSEPH BAXENDELL, F.R.A.S., President of the Section, in the Chair.

The following gentlemen were elected officers of the Section for the ensuing year:—

President:

J. P. JOULE, D.C.L., LL.D., F.R.S., &c.

Vice-Presidents:

JOSEPH BAXENDELL, F.R.A.S.
ALFRED BROTHERS, F.R.A.S.

Secretary:

J. A. BENNION, B.A., F.R.A.S.

Treasurer:

JAMES BOTTOMLEY, D.Sc., B.A., F.C.S.

April 10th, 1883.

Dr. J. P. JOULE, F.R.S., President of the Section, in the Chair.

Mr. BAXENDELL communicated the results of a discussion of the Measures of the Great Pyramid.

T. SOWLER AND CO., PRINTERS, CANNON STREET, MANCHESTER.