MEMOIRS

OF THE

LITERARY AND PHILOSOPHICAL SOCIETY

OF

MANCHESTER.

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NOTE.

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I.—*On the Causes of the Great Currents of the Ocean.*

By Mr. Alderman HOPKINS.

[*Read November 4th,* 1851.]

IN addition to the disturbances produced in the water of the ocean by tidal action, there are extensive movements of it that are known by the name of Oceanic Currents. Different opinions have been entertained respecting the causes of these currents, but they have generally been ascribed to the rotation of the globe on its axis causing the surface of the earth to move eastward, faster than the water which is contained in the bed of the ocean. The influence of wind on the surface of the water has been occasionally recognised, but mostly as a modifying cause, affecting only the surface and the water immediately under it.

For instance, in Lizars' Atlas, which is a popular compilation from what are considered the best authorities, it is said,— "Besides the tides there is a regular motion of the whole waters of the ocean, which carries them from east to west in the tropical regions, and as far as 30 degrees of north and south latitudes in the same direction as the trade winds, but contrary to that of the rotation of the globe." According to Malte-Brun—"The globe, moving with velocity towards the east, leaves the waters of the tropical oceans always a little behind; and hence they seem to move towards the west with a rapidity proportioned to the superior velocity with which the solid parts of the earth really move towards the east." And the writer of the Atlas remarks—"Whatever may be thought of this theory, which it must be confessed is somewhat fanciful, the fact is certain as to the existence of these currents or movements, by which the waters of the sea are carried without any impulse of the wind or tide into a particular direction." "Thus the Pacific Ocean flows from east to west with a motion powerful in proportion to the vast and uninterrupted extent of that sea. This main current in its motion westward is impeded by an immense archipelago of islands and sub-marine mountains. It forces its way into this labyrinth, and then forms a variety of currents."—(p. 35.)

In the same work, in speaking of the Atlantic currents it is said—"The great western current of the Indian Ocean, after passing the Cape of Good Hope, advances across the Atlantic to the American shore; and being opposed by this great barrier the waters divide, and are turned in different directions by the peculiar configurations of the coast. One part makes its way through the Straits of Magellan to the Pacific Ocean; the other stream is better known, it being the great current of the Atlantic Ocean, which is turned northward about the 8th degree of south latitude, and extends towards the eastern coast of America. It is extremely rapid;—it prevails from the 30th degree of north latitude to the 10th degree of south latitude, beginning at from twenty to thirty leagues from the coast of Africa, and extending over all that sea in which the Antilles are scattered. There is a third great current of the Atlantic Ocean, by which its waters, in their progress westward, are carried violently into the Gulf of Mexico, and there, being collected and concentrated, they rush with rapidity through the Bahama Channel."

In the Penny Cyclopædia, where the general opinion on the subject is also given, it is said that "Humboldt, ascribing the formation of these currents to the rotation of the earth, calls them 'currents of rotation.' But he does not distinguish between the proper currents and the drift water, which latter produces a slight western current on the surface of the ocean between the tropics. This latter motion is indeed probably caused by the united effects of the rotation and the trade winds, on the wide-expanded surface of the ocean. The small degree of velocity in this current, however, shews that the stronger currents near the equator cannot arise from the same cause. Rennel thinks that the equatorial currents are caused by the accumulation of great masses of drift-water near the equator, by the north-easterly and south-easterly trade winds. But this opinion will be found inadmissible, when it is considered that such accumulation could only produce a superficial current; and these currents are not superficial, but go to a great depth." Again, in the article on this subject in the Encyclopædia Britannica it is said, that "in the sea, currents are either natural and general, arising from the diurnal rotation of the earth about its axis; or accidental and particular, caused by the waters being driven against promontories, or into gulfs or straits."

Thus, all these writers concur in representing the rotatory motion of the earth as the great cause of the oceanic currents that are found within the tropical regions. This rotatory motion causing the tropical parts of the land to move eastward at a high velocity, as it undoubtedly does, it is assumed that the waters of the ocean must be left behind. But for this assumption there does not appear to be any sufficient reason assigned, nor indeed is any plausible reason given, unless the alleged depths of the oceanic currents can be considered one. But it will be admitted that the weight of the water will cause it to press on the solid bottom of the sea, however deep or shallow the water may be, with a force proportioned to the weight; and it has not been shewn that that weight will be insufficient to enable the solid earth to carry the fluid water with it, and thus to cause both to move with a velocity which, with reference to our present subject, may be considered equal. The assumption, therefore, that the water will be left behind the land, being unsupported by specific evidence, may at present be treated as unproved and unfounded. Of the facts that are furnished there is no doubt, as these oceanic currents are well known to exist; it is therefore of the causes alone that we have to treat, and the great cause is stated by these writers to be the rotation of the surface of the globe making the solid land move faster than the liquid water that rests upon it, which is therefore said to be left behind in its rotation, making an apparent current.

Now, if the rotation of the solid earth really left the water behind, we should have an apparent western current flowing across every part of the open tropical seas, and therefore across not only the Pacific and Atlantic, but also across the Indian Ocean, near the Equator, say from Sumatra to Ajan and Zanguebar on the eastern side of Africa. This ocean is as wide as the Atlantic near to the equator, and therefore would allow the land to pass eastward from the water, if it could so pass, quite as well as in the Atlantic. But there is no such current in this part of the Indian Ocean; on the contrary, the currents that are found in this locality flow towards the east rather than to the west.

On the opposite side of the Continent of Africa, however, there is a very decided oceanic current, but it flows from the west to the east, just in the opposite direction to those "currents of rotation" of which we have been speaking. This current is generally spoken of as being very extraordinary.

Lizars says of it,—" Along the western coast of Africa some singular currents prevail. Between the 30th degree of north and the 10th degree of south latitude (the same breadth as the westerly stream that runs into the Gulf of Mexico) an easterly current sets in towards the shore, which has been sometimes fatal to mariners. By this current, vessels, if they approach too near the coast, are drawn into the Gulf of Guinea, out of which they experience the greatest difficulty in making their way."

Other writers speak of this current in the same manner. One of them says,—" This current, which is known by the name of Fernando Po, is said to be so strong as to impel vessels powerfully towards the bay, when they happen to come too near the coast. Its strength is such that a vessel may, in two days, go from Maura to Rio de Benin, distant 150 leagues; and the time required to return is about six weeks."

In this locality, the land on which the sea water rests, so far from moving towards the east with greater velocity than the water of that sea, most undoubtedly must move with a less velocity, as it allows the water to proceed eastward so much faster than itself, as to constitute that water a strong current running eastward into the Gulf of Guinea. Thus on both sides of Africa within the tropics, the oceanic currents, where any exist, move in a direction the opposite to that which would be found if the theory of which we are speaking were true. There are many other currents that furnish practical evidence of the erroneous nature of that theory; but it is desirable that we should in the first instance direct our attention to those great western currents that have been named, and to the causes which, it may be presumed, really produce them.

In one of the extracts that have been given, some influence is assigned to the winds that blow over the tropical seas, but they are said to produce only a superficial effect on the body of the water, and it is positively asserted that they do not produce the great and deep currents of the ocean. It is necessary, therefore, that we should advert to the nature of the action of the wind, on water over which it is passing, in order that we may see the force of this assertion. The atmosphere presses with a weight of 15lbs. on each square inch of the surface of the water, and when that atmosphere is in motion as a wind it continues to press with the same weight, and by its friction must tend to impel the water forward in the direction in which the wind is blowing. The immediate effect of this wind, as is well known, is to cause a slight ripple on the surface of the water: and afterwards in a short time and in proportion to the velocity of the wind, to produce small or large waves. The waves when formed present a rougher surface for the wind to act on, and they enable it more effectually to force the water forward in a horizontal direction. Now this force being continued for a long time, and acting over a large extent of surface, is, it is contended, capable of producing a great general result, in communicating motion to the waters of the great oceans.

It is known, too, that the gases which constitute the atmosphere, to a certain extent penetrate the body of any water on which they rest; the atmosphere may therefore be considered not to press altogether on the surface of the water, but to some extent on that portion of the gases which the body of the water contains. Now, when the atmosphere over the sea is put in motion and becomes a wind, it must have a tendency to carry with it, not only all the air that is above the surface of the water, but also that portion which has penetrated the body of it, and that is below the surface. How far this circumstance may cause the wind more effectually to carry with it the water over which it is passing may not be known, but the tendency of a wind to produce such an effect is sufficiently apparent.

That wind such as has been described, acting on the surface of water, will put it in motion and to some extent produce a current, is so evident, that it must be and indeed is admitted: but it is said that currents produced by this cause are superficial, whilst the tropical currents are of great depth. The depth of the current, however, may depend on the velocity with which the wind blows, the constancy of its action, and the extent of water on which it acts. When the wind first presses on the water, it appears to act on the surface alone; but when that surface is put in motion, the upper water, while in motion, presses on that which is lower, and carries it also forward in a horizontal direction; and this pressure of the water while in motion is propagated to greater depths, so long as the pressure of the wind on the surface is continued. For the wind, moving as it does with greater velocity than the water, exerts its force in every successive instant of time, like gravity in the descent of bodies, and that force is added to all the previous effect that had been produced. And over a wide ocean, there is no reason to be assigned that the pressure of wind, acting constantly on the surface of water, should not give motion to that water even at great depths.

The tropical trade wind of the Pacific Ocean, in which exists one of the great oceanic currents that have been named, is first found moving slowly near to the Galapagos islands, in say about 90 degrees of west longitude, where it produces but a slight effect on the water of the ocean: but it continues blowing westward, and generally with increasing velocity, over not less than say 120 degrees of longitude, or 7,200 geographical miles; there is therefore, over this ocean, sufficient space to permit the action of the comparatively rapid wind on the surface of the water to press that water forward with increasing rapidity, and to greater and greater depths, and the current thus created, by the wind alone, may, it is contended, be found to extend to great depths.

Another wind of the tropical regions,—the trade wind of the Southern Atlantic, appears to have its origin in so remote a part as near the western coast of Australia. From between say 20 and 30 degrees of south latitude, wind blows from the east across the Indian Ocean, and it apparently carries with it the waters of the ocean, as an oceanic current sets on Madagascar and the southern part of Africa. It then passes across the Southern Atlantic, as a south-east wind, extending to the coast of Brazil, followed throughout its course by the water of the ocean. A part of this water, being impelled by the wind through the Caribbean Sea and into the Gulf of Mexico, is there accumulated and raised to a higher level, until it finds an outlet in the channel between Florida and the island of Cuba, along which channel it passes as the well-known Gulf Stream. Now wind, acting constantly on the surface of water as these trade winds do, and over the extent of two great oceans, must, for the reasons that have been given, be considered fully able to set that water in motion, not merely on the surface or a little below it, but to a depth quite equal to that at which the currents are found in the Southern Atlantic, the Caribbean Sea, or the Gulf of Mexico.

The eastern trade wind of the Northern Atlantic in like manner traverses the surface of the part of the ocean that lies between the Canary Islands and the West Indies, taking water with it, which water, in conjunction with that which comes from the Southern Atlantic, is forced into the Gulf of Mexico; and the water of these two currents is, by its accumulation and acquired velocity, carried northward to the bank of Newfoundland, from which it is deflected across the Atlantic.

It is evidently the same kind of force, namely, the force of the wind acting on the surface of water, that produces the oceanic current that has been already alluded to, in the Gulf of Guinea, which, to the surprise of the rotatory theorists, flows in an opposite direction to those just mentioned! A strong wind from the west here traverses only a moderate extent of sea, and blows into this gulf towards the shore; yet this wind, short as is its course, evidently forces the water forward and creates the oceanic current, no other cause being found to produce it in this case. But if wind, by blowing over so comparatively small an extent of sea, can produce such a rapid oceanic current as that which exists in the Gulf of Guinea, there can be no reason given that the same agent should not, by passing over the Pacific, the Indian, and the Atlantic Oceans, produce strong currents in them.

It has been long observed that wind blowing over water towards land, acts on water which is obstructed by the land, with a force sufficient to raise it to a considerably higher level than it would otherwise attain. This has been particularly noticed in the river Thames, where a strong wind acting in the same direction as the flowing tide, raises the water much above the proper tidal elevation, whilst the wind acting in the opposite direction to the tide produces a contrary result: the same effects are experienced in the Severn. In the canal between Runcorn and Manchester which has a level of considerable extent, the wind, when it blows strongly from Runcorn, raises the water above the true level at Manchester. The same kind of effect is produced in the Forth and Clyde Canal. When the wind has for some time blown strongly from Suez, at the head of the Red Sea, it is said that the water of that sea has been forced southward to so great an extent, as to leave the bed of the sea almost fordable, though, at other times it is deep. Mr. Taylor, the astronomer at Madras, informs us that "the north-east monsoon sets in at that place about the 19th of October, and along with the wind a current sets along the shore. It reaches its maximum velocity about the 1st of November, running then three miles an hour. During this interval the sea, on a squally day, rises two and a half feet above and sinks two and a half feet below its mean level, and, in the case of a gale of wind, it may possibly reach to double this amount." "On the 21st May 1833, a terrible storm raged in the Bay of Bengal near the mouth of the Hoogly, when the tide, at the mouth of that river, rose more than twelve feet above the ordinary height of the springs!" These are a few of the numberless instances which might be adduced to shew that wind, acting on the surface of confined water, produces upon it great effect in raising its level; but when there is ample space for the water to move forward, the wind readily produces a current, and it is evident from the nature of the force that is in action, that that current will, in deep water, extend to depths proportioned to the length of time that the wind has acted on the water which is in motion.

There are parts, other than those which have been mentioned, where winds evidently create oceanic currents. One blows from the south along the western coast of South America, and an oceanic current is found moving with it, increasing in velocity with the increase of the wind and carrying comparatively cold water even to the equator. This current of the ocean runs from south to north, and not from east to west, as the so-called rotatory currents do; the surface of the land therefore moving easterly, faster than the water resting on it, cannot account for this current, which must be produced by the wind. There is another extensive current which is thus described:—"In the Indian Ocean we find the well known current that runs from south to north, from the west coast of New Holland, (Australia,) and from the Island of Sumatra, as far as the bottom of the Gulf of Bengal." It also "impels one of its branches through the Strait of India; thence it runs with great violence into the Chinese Seas, and was found by La Perouse to be of great strength in the Sea of Japan, and in the Channel of Tartary." (p. 35, *Lizars.*) This great current, it appears, has to cross the equator near Sumatra, from which part there is open sea extending say three thousand miles to the coast of Africa, and if the water of the ocean were here left behind by the land, it would have an apparent current westward, that is in the direction of Africa! But we see that it runs not west but north, into the Bay of Bengal, and then passes to the east through the Indian and Chinese Seas. This extensive oceanic current, therefore, which directly crosses the equator, and which, in the Indian and Chinese Seas, runs eastward, and therefore rotates faster eastward than the land, cannot be water left behind by the land.

But, it is in those parts of the world where the direction of the oceanic currents changes with the season, that we have the strongest proof of the errors of those writers who attribute the currents to the rotatory motion of the earth. That motion is always the same, quite independent of seasons, and any effect really produced by it would be undisturbed by changes in the seasons; this would be more particularly the case within the tropical regions, where the rotatory motion of the surface of the earth is the most rapid. Now, over the northern Indian Ocean, the Bay of Bengal, and the China Sea, the south-west monsoon prevails during summer, and the north-east monsoon blows during the winter. And the oceanic currents of these parts of the world are found to obey, not the rotatory motion of the earth, as they should according to the rotatory theory, but for the time the influence of the prevailing wind,—changing regularly with the change of the season. Thus we are told by one writer that "between Cochin China and Malacca, when the western monsoon blows, that is, from April to August, the current sets eastward against the general motion. In like manner for some months after the middle of February the currents set from the Maldives towards India on the east, against the general motion of the sea. Varinius says that at Java in the Straits of Sunda, when the monsoon blows from the west, that is, in the month of May, the currents set to the eastward contrary to the general motion. Between the islands of Celebes and Madura, when the western monsoon sets in, that is, in December, January, and February, or when the winds blow from the north-west or between the north and west, the currents set to the south-east or between the south and east." —*Rees' Cyclopedia.*

Davidson, in an account of his voyage in this part of the world, says,—"From April to September the south-east monsoon blows in Torres Straits, and the westerly monsoon prevails during October and the five following months, and these last winds blow so strongly as to close the passage of those straits," (from the Pacific.) He also further states that "the barrier reef extends from the coast of New Holland (Australia) to that of Papua, (or New Guinea,) with numerous gaps and entrances in it, which appear to be kept open by the current that for six months in the year runs through them from the Pacific to the Indian Sea, and in the contrary direction during the other six." (p. 214.) It thus appears that during one half of the year the wind blows from the Pacific Ocean through these straits, and then the oceanic current runs through them from the Pacific; but during the other half the wind blows from the Indian Ocean, and then the current runs with it from that ocean. If the solid land in its rotation towards the east left the water behind, and gave it an apparent motion towards the west, it most undoubtedly would run westward here from the wide Pacific Ocean, in the winter as well as in the summer,—from October to March, as well as from March to October,—seeing that the rotatory motion would always produce precisely the same effect. But as it does not do so, we must conclude that it is the changing wind that produces the currents which so uniformly change with it.

These accounts of the alterations of the oceanic currents with the change in the direction of the wind, are mostly given by writers who supposed that the rotation of the earth was the great general cause of the currents, and they speak of the altered direction of the water in the particular cases with surprise. There is, therefore, every reason to place confidence in their accounts; and their statements shew not only that wind can produce rapid motion in the water of the ocean over which it passes, but that it produces the motion in a short time, and while passing over only a limited space. It is always soon after the wind changes that the ocean current changes, and many of the currents run with great force in a direction exactly contrary to that which is erroneously supposed to be their natural direction consequent on the rotation of the earth. But if within these comparatively limited spaces wind can soon put water in rapid motion, it is sufficiently evident that the same wind acting on the surface of broad oceans, and for a much longer time, is capable of producing proportionately greater effect, and it may therefore be admitted to be able to create the currents that are found in the widest and deepest seas.

It has thus been found that all the great oceanic currents that have been pointed out are accompanied by winds; that, although they sometimes move in accordance with the rotatory theory, they at other times run in opposition to it, but they always run in the direction of the wind, and they change as the wind changes. The evidence against the rotation theory may therefore be said to be strong and complete, and that theory may be considered erroneous.

As a consequence of the greater rotatory velocity of the surface of the globe within than without the tropics, it has long been believed that within the tropics the surface of the earth, in its rotation, left the atmosphere behind, and thus produced the eastern tropical trade winds. And certainly, from the greater velocity of the air than of the water of the sea when passing from a slower to a quicker rotating latitude, this was not an unreasonable conjecture; the Hadleyan theory of winds was therefore plausible. But it has been proved that even the air soon acquires the rotatory velocity of the portion of the globe on which it presses, and is then just as ready to obey local influences as if both itself and the surface were without rotatory motion. But if air with its lightness and elasticity thus rapidly acquires the motion of the part of the earth on which it rests, how much more decidedly must heavy and comparatively inelastic water do so? Yet it is very probable that the opinion so generally adopted, that the tropical trade winds were caused by the earth leaving the air behind it, countenanced, if it did not give birth to the belief, that the solid earth, in its rotation, left the waters of the ocean behind. I am not aware of any proof having been furnished of the superior rotatory velocity of the bed of the ocean, as compared with that of the water resting on it. It appears to have been voluntarily assumed, in order to assign a cause for the great oceanic currents, as no other adequate cause could be found. But when it is seen that wind has sufficient power to produce, not only the great eastern oceanic currents, but also the other currents which run in different directions, and with great velocities, and that wind is always in action wherever the currents are found, such an assumption becomes unnecessary and may be discarded.

The waters of the ocean are partially confined within basins having bottoms unequal in depth, with sub-marine mountains and vallies, bounded by land of irregular forms; and an ocean current created by wind within any basin may obviously have its direction altered by a sub-marine valley or mountain, just as the direction of wind itself may be changed or modified in passing through a valley above the level of the sea. And when a force like the action of wind, in some particular locality, raises water much above its natural level, as it does in the Gulf of Mexico, the gravity of the water immediately acts to restore the equilibrium of pressure, and may thus produce new currents. It is not, however, the object of this paper to pursue secondary oceanic currents through their various courses,—that object having been only to point out the real primary cause that puts in motion the waters whose movements constitute the great currents of the tropical seas, which are the great currents of the ocean. And this cause it is contended is the Wind,—which, itself produced by condensing vapour heating the atmosphere in particular localities, blows towards those localities, taking the water of the ocean with it, uninfluenced to any appreciable and palpable extent, by the rotatory motion of the surface of the globe,—thus shewing that *Wind* is the real cause of the great oceanic currents.

II.—*Some Remarks on "The Deserted Village" of Oliver Goldsmith.* By Mr. J. Y. Caw, F.S.A., Scot.

[*Read November* 18*th*, 1851.]

"The Deserted Village" is a poem full of interest, from the circumstance of the accuracy of its descriptions, and their great fidelity, joined with its elegant and unostentatious language. The simple scenes which it professes to describe are so familiar, as to render the multitude qualified to judge of the poet's correctness; while the manner in which he paints the characters of every-day life, draws admiration from those whose powers of criticism have been cultivated by the study of general literature, and whose judgment has been matured by experience. The characters which severally claim attention in this beautiful poem are immediately recognised, and the accuracy of the poetical description is clearly apparent.

The scene of this poem is a village which has been deserted by its inhabitants, who have emigrated to other lands and left the home of their fathers, formerly full of happiness and plenty,—a place

"Where desolation saddens all the green."

The cause assigned for the change which is so pathetically described, is the advancing luxury of the age, which, not content with the happy population, ejects them for the purpose of extending its parks, and enlarging its drives.

The poet takes the part of those who are suffering from this measure of ambition, and throws into his subject much humane feeling, mingled with honest indignation. He warms with his subject, and hesitates not to denounce the luxury to which he attributes the evils which he depicts, as a vice of the blackest enormity and most dangerous quality. But while he attacks Luxury as the depopulator of his country, he at the same time accuses Commerce as the chief cause of the evil. He draws the picture of a barren waste,—solitary, without inhabitants, and without cultivation; and having contrasted the beauty of rural life in a happy village, with the scene of his imagination, condemns Commerce as the cause of the change, and in his desire to defend the peace of rural happiness, hesitates not to accuse the enterprise of trade as an evil which must eventually ruin the country, and drive from it not only population but virtue. So long as he confines himself to the delineation of the rustic population,—to the painting their sports, habits, and occupations,—or pictures the village church and the school or parsonage, every one must admit the accuracy of his description and the force of his language. But when he begins to reason as to the causes which have operated to bring about the state of things which he describes, his arguments appear weak and his illustrations absurd. The beauty of the poem will compensate for this failing with ordinary readers, who can appreciate the scenes which he paints, though they will pass over without much consideration the deductions which he draws.

In truth, the poet would have been deficient in feeling had he not, after lamenting the desolation, denounced the Desolators; and after he had discovered what he conceived to be the cause of the evil, he was compelled to pour out all the indignation of poetical justice upon the offenders. Yet when we analyse his pathetic appeals, it will appear they are more imaginary than real. If they were correctly stated as having existence, then perhaps his lamentations would demand our sympathy; but the fallacy lies in his imagination having invested with the power and the will of devastation and ruin, that Commerce which the practical facts of every-day life shew to have directly the opposite tendency. If since this poem was published, the whole course of events in this country goes to contradict the existence of such a scene of desolation, the present state of Great Britain but renders the refutation more complete. If one of the most frequently quoted passages of the poem be examined, it will be found to be a mixture of fallacy and truth; nor would it be worth while to allude to it, were it not a favourite quotation with those who seem never to be so happy as when they are mourning over the anticipated ruin of their country, and predicting its speedy and irreparable downfal.

> "Ill fares the land—to hastening ills a prey—
> Where wealth accumulates, and men decay;
> Princes and lords may flourish or may fade,—
> A breath can make them as a breath has made;
> But a bold peasantry, their country's pride,
> When once destroyed, can never be supplied."

These lines are familiar to every one; and all must regret the condition of the country given over to such an evil as the accumulation of wealth, and the diminution of the population. But in truth, the one is incompatible with the other. The increase of wealth is attended with an enlarged population, which, in fact, is one great cause of the accession of riches. Instead of villages being deserted, they grow into towns, and hamlets become villages under the influence of active commercial industry; while capital accumulates from the additional activity which the energy of an increased population brings to bear upon its creation. Nor do men decay while this is going forward. The greater the extension of the field of manufacturing, commercial, or mercantile industry, the greater the demand for all sorts of agricultural produce; and consequently, the less chance of commerce being the cause of the decay of men, even among that part of the population which may be termed strictly agricultural. The people in rural districts soon increase to such a degree, as not all to be able to find subsistence, and then migration must take place either to some other spot in their own country, or to other lands. Such, however, is the elasticity of population, that many may emigrate before the country can sensibly feel their loss, so soon do others arise to take their place. The fact of emigration going forward is sometimes adduced as an evidence of the country approaching to a state of decadence, while, if rightly viewed, it conveys the idea of a people increasing from prosperity, and compelled to seek new channels for the exertion of their industry. Commerce, instead of contributing to the downfal of a country, is a powerful assistance in mitigating the evils which naturally arise from a rapid increase of population, as it affords to many occupation both at home and abroad,—binds colonies to the native country, and, preserving alive the patriotic feeling, assuages the pain which emigrants may feel upon leaving their homes and setting forth for the purpose of pitching their habitation in a far distant land.

But this forsaking of the country for the town, or of one country for another, is not a depopulating process to be lamented and mourned over, as if ruin were to be the inevitable consequence. We have only to look around us to see the effects of a population gathered from other districts of the country, employed in actively accumulating wealth, without any decay of men; being, besides, the consumers of agricultural produce to such an extent, as to render the rural districts more populous and prosperous than ever they were known to be before. The "bold peasantry," in spite of the predictions of orators, have not yet been destroyed. They live on in spite of the lamentations which are periodically made as to their extinction. Doubtless the lines which we have pointed out, as containing a mixture of truth and error, mixed up in strange confusion, are correct in so far that, when once the peasantry *is* destroyed, it cannot again be supplied; but there is not much fear of that event taking place in our own happy country.

Nor is our poet more fortunate as he proceeds:—

> "A time there was, ere England's griefs began,
> When every rood of ground maintained its man."

With poetic licence, we are informed that there was once a time when happiness prevailed, and when the evils of humanity were unknown;—a golden age, when pain and misery were not the torments of the human race, which experience too bitterly assures us they now are. The ancient poets held the same notion: they all lived in degenerate days, and have, in consequence, looked back upon a period which history assures us never existed, which they have employed their art to describe with elegance, and which they have clothed with the attributes of tranquillity and abundance. The Greek and Latin Poets mixed up with this period of primeval bliss, the Mythology which they dignified with the beauty of their verse, and the glimpses of truth encompassed with error which had been traditionally handed down from generation to generation. The English Poet does not carry his imagination so far back, but refers to a time when England had not experienced those griefs which have in later days, according to poetic accounts, rendered her but a melancholy ruin of what she formerly was.

If we seek for this time of happiness and bliss, we shall have some difficulty in finding it. We cannot expect to discover it among the inhabitants of Britain, when Cæsar found them painted as much for warmth as ornament; nor among their immediate successors, subdued by the Roman arms. Nor does it appear amidst the turbulent invasions of

Danes, Saxons, and Normans; nor in the contest which was perpetually carried on between Saxons and Normans after the Norman Conquest. Nor do we find the high and palmy days of Feudalism and Chivalry more likely to answer the poet's imagination, when instead of each man being maintained by himself, he formed part of the retinue of the baron, whose vassal he was, and whom he was bound to follow and to serve. Nor do the wars of the Roses, the contests of the Stuarts, or the disturbances of the Great Rebellion, promise more. In short, the period described cannot be found in the chronicles of reality. Yet, perhaps the nearest approach to this imaginary state is, after all, at the present day, when the multiplied improvements in all branches of the Arts and Manufactures have been diffused so abundantly, as to increase the comforts and happiness of the great mass of the population, and to bring within their reach enjoyments and advantages which, at a comparatively recent date, were not enjoyed by the nobility themselves.

If, however, the time when every rood of land maintained its man, is not easily discovered, there are nevertheless, visionary speculators who would, with the same false reasoning, endeavour to persuade the ignorant, that land being the favourite investment for capital, it is only necessary for the working man to purchase a small portion, and, uninstructed in rural arts, and unaccustomed to country life, he may expect not only to gain a subsistence, but to make himself of some consequence in the country. This vision has had a melancholy and complete refutation by experiment, and it is hoped the credulity of honest but mistaken men may not again be made the means of unprincipled adventurers robbing them of their limited capital.

The poet describes the scene of desolation as carried to such an extent, as to drive the inhabitants of sweet Auburn

——— "to distant climes,—a dreary scene,
Where half the convex world intrudes between."

But while emigrants must always experience sorrow at leaving their own native land, and their feelings must be excited at parting with associations which they love and respect, still, in a country where the population keeps increasing, it is an evidence of wisdom and prudence to remove to places where there is a greater field for exertion. Nor is it desirable that only the idle and dissipated should be expatriated, when they have perhaps thrown away golden opportunities, for these are little likely to do credit to their country, or to gain advantage for themselves in distant places. But the prudent and industrious may frequently, when their facilities at home are limited, advantageously go abroad, and carry with them Civilization and Arts to places where they may be enabled to develop abilities which here must have lain dormant. And to this very emigration does this country owe much of its greatness. For the sending forth of her sons and her daughters to her colonial possessions, has opened up new channels for commerce, and new markets for manufactures; while a healthy and vigorous population has been reared, who are alive to the comforts, the conveniences, and the elegancies of civilized existence; and the condition of all parties has been improved by the operation.

These remarks are to be understood generally: there are and always must be exceptions. The constitution of society is such as to furnish anomalies,—to present us with want in the midst of plenty, and with sorrow while all around is rejoicing. Yet, on the whole, the advantage is on the side of active exertion; and many of the calamities of life are caused by supineness, or brought on by indolence, and its consequence, dissipation. For these there seems to be no effectual or absolute cure. But one thing is certain, that the patient industry which feels a want of adequate remuneration in one country, is generally possessed of sufficient strength of mind to betake itself to another, where it may meet with the due reward of its exertions.

It may here be noticed, that all the woes and evils of life have always been embraced by the poets as subjects congenial to their art. The personal experience of the individual men may perhaps account for that acute sympathy which they always display for the wretched and unfortunate. The difficulties of the young aspirant for poetic fame, may frequently enlist his feelings on the side of the oppressed. The kindly disposition of the poetic race is a marked characteristic. Indeed, the generous and noble sentiments prevail among them, not only in the choice of subjects, but in their manner of treating them. Hence they are generally the friends of freedom, the advocates of liberty, the denouncers of despotism, the approvers of constancy in love, and the admirers of bravery in the fight. From these circumstances, the volumes of the poets are always favourites with the more enlightened part of mankind, as well as with those who boast of little knowledge but that of the modest train of the duties of every-day life. Goldsmith, while he has elegance of language, possesses a pathos of description which renders his poetry agreeable to all classes. Few poems are so well known as "The Deserted Village," and few more deservedly appreciated. The taste of the most cultivated is pleased with the poem, while the very school-boy is taught extracts from it which he never forgets, and which he admires the longer he knows them. This is a great tribute to the author, who seems to have erected a monument of fame more durable than the marble, and more lasting than the time-defying brass.

The nature of this poem precludes many of the higher branches of the poetic art, yet it is not the less pleasing to a general reader. Descriptive poetry attempts nothing that is grand, but clothes with elegance of language those objects which it embraces. In this poem, in particular, no redundancy of language appears, no repetition which pains the understanding; and so closely is it written, that almost all the descriptions would appear inadequate by the omission of a single line.

Take, for example, the lines which bring before us the evening scene in the village, endeared to the memory of the poet, before the change he deplores had passed upon it, and we shall perceive the beauty and adaptation of his language:—

> "Sweet was the sound when oft at evening's close,
> Up yonder hill the village murmur rose;
> There as I passed with careless steps, and slow,
> The mingled notes came softened from below;—
> The swain responsive as the milkmaid sung,
> The sober herd that lowed to meet their young;
> The noisy geese that gabbled o'er the pool,
> The playful children just let loose from school;
> The watch-dog's voice that bayed the whispering wind,
> And the loud laugh that spoke the vacant mind;—
> These all, in sweet confusion, sought the shade,
> And filled each pause the nightingale had made."

These lines are pleasing, because they are natural. The every-day occurrences of rural life, incidents trivial in themselves, yet placed together, delight on account of their being the description of what every one can realise;—evening passing away,—the sun going down, and universal nature preparing for repose,—the poet's irregular walk, full perchance of pleasure in listening to the sounds he describes,—the mingling notes falling upon his ear without an effort, and the transition which follows on pointing out a variety of sounds softened by distance, and then the idea connected with each cause of sound, some one or other of the objects which formerly rendered Auburn the loveliest village in the plain.

> "The swain responsive as the milkmaid sung."

Here is, in one line, pointed out one of the hardy villagers—strong, active, handsome, and laborious—relaxing from the labours of the day in simple strains, and accompanied by one of the softer sex, who, delighted with the attentions of her rustic lover, sings with a light heart a cheerful song, awakening a response from him; and thus, in true rural simplicity, artlessly entwining the affections of her lover. Around them, in the field, are the "sober herd," displaying the characteristic fondness of the dumb creation for their offspring; while the "noisy geese" are amusing themselves in the pool, their distracting cackle softened by the sweeter sounds around; while the "playful children" keep before us the idea of a contented and happy population, with which the poem commenced, which is still strengthened by the "loud laugh" which comes from among a crowd of villagers, and the "watch-dog's bark," who has no more substantial object of pursuit than the murmuring breeze. All these, in sweet confusion, are said to "fill the pause the nightingale had made." This brings us back to the poet, who, listening to the sounds, has only done so during the intervals of the sweet song of nature, of which true poets are always ardent admirers. This scene was one which gave Auburn much of its interest in the poet's affections, and accordingly he goes on to contrast the present state of "The Deserted Village" with its former condition. All these have now passed away, and the Muse sings in melancholy strains the unpropitious change. The "cheerful murmurs" of a happy and contented population no longer "fluctuate in the gale;"—the footpath, overgrown with grass, is no longer trod by the busy steps which proved the existence of the "blooming flush of life," the absence of which is so pathetically deplored; and but one solitary inhabitant is represented as deriving a miserable subsistence by stripping the "brook with mantling cresses spread."

The picture drawn of the modest mansion of the village preacher is but an introduction to describe the minister himself. Chaucer has, among the characters in the Canterbury Tales, a "poure persone of a toun," whose life is described with his usual quaintness and accuracy, and who is pointed out as a model. Goldsmith's village clergyman is much more fully pourtrayed, and in a different style. Indeed, though both have distinctly brought forward a character familiar to all, yet there is no such similitude existing as to lead to the idea of any plagiarism. That they have expressed the same notions in one or two instances was certainly to be expected, and hence we find Chaucer saying—

> "To drawen folk to heaven with fairenesse,
> By good example was his besinesse;"

while Goldsmith, amplifying his subject, conveys the same idea with a beautiful comparison—

> "And as a bird each fond endearment tries,
> To tempt its new-fledged offspring to the skies;
> He tried each art, reproved each dull delay,
> Allured to brighter worlds, and led the way."

It is unnecessary to adduce any further coincidence between these two celebrated passages. Our poet has, with a minuteness which never distresses, and an exactness and accuracy which please the more the poem is examined, completed his portrait of one of the principal characters of the village, with one of the most beautiful similes of which the English language can boast:—

> "As some tall cliff that lifts its awful form,
> Swells from the vale and midway leaves the storm;
> Though round its breast the rolling clouds are spread,
> Eternal sunshine settles on its head."

Another poet of a subsequent age has taken the same subject in hand. Cowper, in his Task, has described a preacher, but his manner is so full of caustic satire, directed against those whom he should not imitate, and against practices that he should not follow, that he has failed to convey to the minds of his readers the very ideas which he labours to impress. The severity of his tone takes from the beauty of his verse, whilst the excellencies of the character are made more to consist in his oratory, than, as the case is with Goldsmith, in the quiet, unpretending excellency of his life. Cowper depicts a popular speaker; Goldsmith a good man, endeared to those around him by the excellence of his conduct, the kindness of his manner, and the disinterestedness of his benevolence, more than by the fervour of his eloquence or the purity of his precepts. Cowper shews us the man who can address himself with effect to an educated congregation; Goldsmith the unsophisticated being whom

> "E'en children followed with endearing wile,
> And plucked his gown;"

and yet, beloved as he was by all classes of the community,

> "All his serious thoughts had rest in Heaven."

Dryden has attempted the same theme and at greater length; he has, in fact, amplified Chaucer, and presented the ancient poet's description in more modern language.

The next character brought before us is the village schoolmaster, who, if not so important as the last, is not the less useful. Those points in his character which tend to excite a smile are the necessary consequence of the position of such a person, whose acquirements are always superior to those by whom he is surrounded, a circumstance which tends to encourage a degree of self-confidence which enables him, though vanquished in argument, still to argue. This and much more may willingly be conceded to him who has such an arduous daily labour as that of governing a school of unruly boys. The schoolmaster has frequently a difficult task to pursue between his duty to the pupils and the foolish fondness of ignorant parents; and if such persons are in their fretfulness apt to exclaim against the acerbity of the teacher, the quiet patience which the great body of those engaged in tuition generally possess, cannot fail to be appreciated by those who reflect upon the difficulties of their position, in a little world where the evil passions are striving for dominion, and which it is their constant endeavour to curb and repress. There must be many an anxious thought when admonitions are disregarded, and instruction neglected; but on the other hand, assiduity is rewarded by perceiving those who have been well trained adorning their station in society, whatever that may be, by fulfilling their duty in a manner creditable to them and to their instructors.

The village master is said by the poet to be "skilled to rule," "severe," and "stern to view;" and justly so under the circumstances, "for every truant knew" his severity was against those who neglected their duty, and avoided his instructions, for he afterwards is described as being kind, his love to learning being the apology for his exercising discipline upon offenders. The inhabitants treated him with due respect, and their astonishment appears naturally and accurately expressed, when, not being able to understand his words of learned length, they yielded to him such homage as was due, and wondered

"That one small head could carry all he knew!"

The parting scene, where the inhabitants are supposed to be about to leave their native place for the Western World, deserves particular attention. The poet has here, in accordance with the tone which runs through the poem, painted the grief which was experienced on leaving a place which they all loved, while the uncertainty of their future fate heightens the mournful scene. There is here no effort to create effect: the language is plain, and the beauty of the description is its complete fidelity to nature. It may naturally be supposed that whatever motives might lead to the determination of a family to leave their native land, still, when the time arrived for their departure, the feelings embodied in the poem would most naturally arise. At that eventful moment the hopes and expectations of a distant voyage would vanish, before the reality of the last look upon a home of former happiness. Ambition would for a moment be subdued by patriotism, and even avarice would spare a tear on the mournful occasion. Few scenes can be supposed to be more affecting than such a departure. The young man may set forth in the vigour of youth to push his fortune in far distant countries, but there lurks in his tears at parting a bright hope of a future return, which gilds his prospects, as the rainbow, spread over the broad arch of heaven, adorns the darkness of a clouded sky, and is the earnest of a serene and peaceful evening. The daughter wedded to a faithful lover, embarking for distant lands, has a prop whereon to lean the weaknesses which might otherwise overpower her, and the hope perchance of sending her offspring homewards, as pledges of her own expected return; while parents thus separated from their children, indulge the fond hope of a future meeting, and are cheered by the possibility of their lives being prolonged, and circumstances permitting that pleasing reunion; but when, in one band, the aged and infirm, the man in the prime of his vigour, and the little babe of yesterday, all leave the beloved home together, there is a pang of bitterness at the last moments of their existence spent in their native place, which few can attempt to describe, although with the poem before us few can avoid conceiving.

"The good old sire the first prepared to go
To new-found worlds, and wept for others' woe;
But for himself, in conscious virtue brave,
He only wished for worlds beyond the grave.
His lovely daughter, lovelier in her tears,
The fond companion of his helpless years,

Silent, went next, neglectful of her charms,
And left a lover's for a father's arms.
With tender plaints the mother spoke her woes,
And blessed the cot where every pleasure rose;
And kissed her thoughtless babes with many a tear,
And clasped them close, in sorrow doubly dear;
Whilst her fond husband strove to send relief
In all the silent manliness of grief."

III.—*A new Discussion of the General Equation of Curves of the Second Degree.*

By Mr. Robert Finlay, Professor of Mathematics,
New College, Manchester.

[*Read December 2nd,* 1851.]

The method of representing the position of a point in a plane is the fundamental principle of the Cartesian Geometry. To understand this method, let Ox and Oy (Fig. 1) be two straight lines cutting each other in O, and P any point in the same plane. Draw PQ and PR parallel to Ox and Oy; then, if the lengths of PQ and PR be given, the position of P in reference to Ox and Oy may be considered as known. Hence PQ and PR are called the *co-ordinates* of P, and they are denoted respectively by x and y. The lines Ox and Oy are called the *axes of co-ordinates,* and are always either given or assumed. The point O is called the *origin of co-ordinates.*

If this method of determining the position of a point be viewed in connexion with the well known algebraical fact, that any equation containing two variables, such as

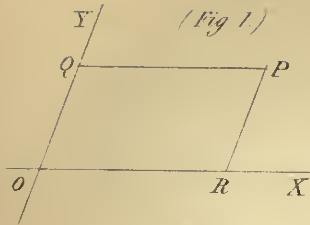
$$2\,x^2 + 3\,xy = 5,$$

can be satisfied in an infinite number of ways, by assigning particular values to x and corresponding ones to y, it will readily appear that any algebraical equation containing two variables can represent an infinite number of points; and it is easy to show that all these points lie in a certain curve, which is called the locus of the equation. Conversely, it is evident that every regular curve must have an equation, and by means of this equation any question relative to the properties of the curve may readily be reduced to algebraic form. Thus, by means of the simple conception of Descartes, the science of geometry was brought within the range of algebraic analysis, and it acquired instantaneously a generality and power which had not been imparted to it by the united efforts of many of the greatest men of antiquity.

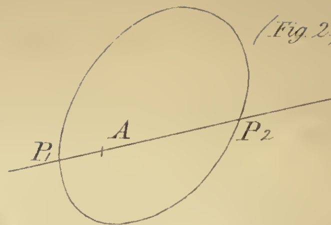
From the statement which I have just made relative to the first principle of the Cartesian Geometry, it will be perceived, that, in that system, the investigation of the properties of any curve depends on the discussion of the equation to the curve. When the equation is of the second degree, its discussion can be effected without much difficulty, and in a tolerably complete form. The numerous papers on this subject, however, which have appeared from time to time, and some of which are of very recent date, prove sufficiently that the present mode of discussing the equation of the second degree is not altogether satisfactory; and this constitutes the most obvious apology which I can offer for introducing to this Society a subject so well known to mathematicians of every degree of attainment.

The common method of discussing the general equation of the second degree consists mainly in a process called the *transformation of co-ordinates*. The co-ordinates of a point may be changed in two distinct ways. 1st. By simply changing the origin, the axes remaining parallel to their original directions. 2nd. By turning the axes about the origin into any new positions. The known formulas for the former transformation are so simple and natural that nothing further on that point can be desired. Those for the latter, on the contrary, are exceedingly complicated; and they have

(Fig 1.)



(Fig. 2.)



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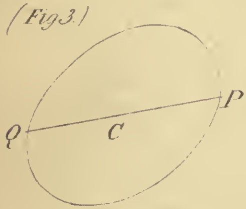

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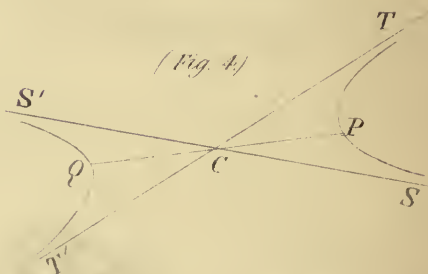

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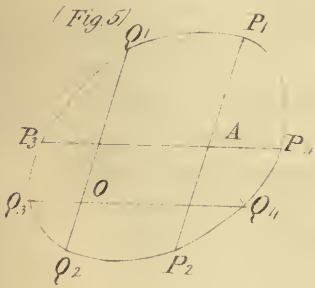

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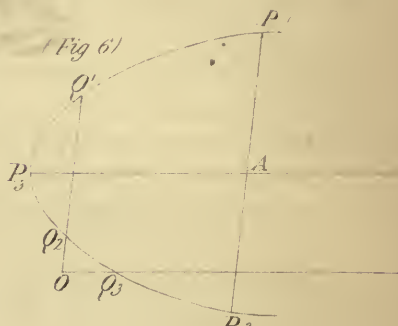
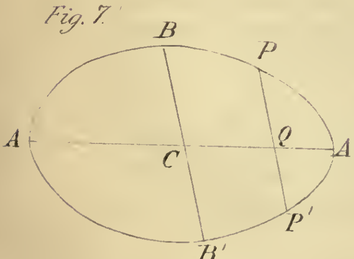
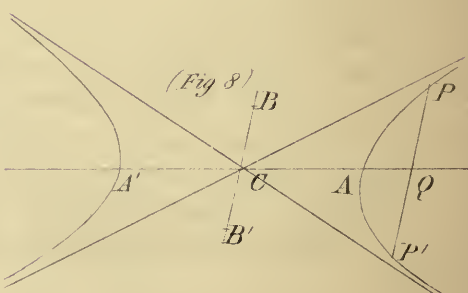


Fig. 7.



(Fig 8)



the disadvantage of introducing such a multitude of trigonometrical symbols as to give the whole discussion the appearance of a chapter on trigonometry.

In the method which I propose to substitute for this latter transformation, the science is made to depend on its own resources and notations, with little or no reference either to the theorems or symbols of trigonometry. Another important advantage of the method which I propose is, that the investigations relative to oblique axes are very little, if at all, more difficult than those which relate to rectangular axes. For the sake of brevity, I have confined myself throughout the paper to the most general case in which the co-ordinates are oblique.

I.

The equation of curves of the second degree can always be reduced to the form

$$Ay^2+2\,By\,x+Cx^2+2\,Dy+2\,Ex+F=o\ldots\ldots(1),$$

where A is a positive integer, and B, C, D, E, F may be positive or negative integers. For, if the co-efficient of y^2 be negative, it may be made positive by changing the signs of all the terms of the equation; and if the co-efficient of x, y, or xy, be odd, it can be made even by multiplying the whole equation by 2.

Let R be the distance from a given point A $(x_1\,y_1)$ to any point xy on the curve (1), then by the theory of the straight line

$$R^2=(y-y_1)^2+(x-x_1)^2+2\,(x-x_1)\,(y-y_1)\cos\gamma,$$

γ being the angle made by the positive axes of x and y. Again, let m be the direction index of the straight line R; then

$$y-y_1=m\,(x-x_1)\ldots\ldots\ldots\ldots(2),$$

and in virtue of this, the preceding equation becomes

$$R^2=(x-x_1)^2\,(m^2+2\,m\cos\gamma+1)\ldots\ldots\ldots(a).$$

Now since $Ay^2=A\,(y-y_1)^2+2\,Ay_1\,(y-y_1)+Ay_1^2,$

$$Cx^2=C\,(x-x_1)^2+2\,Cx^1\,(x-x_1)+Cx_1^2,$$

By $x = B(y-y_1)(x-x_1) + By_1(x-x_1) + Bx_1(y-y_1) + Bx_1 y_1$,

$$Dy = D(y-y_1) + Dy_1, \quad Ex = E(x-x_1) + Ex_1,$$

equation (1) may be written in the form

$$A(y-y_1)^2 + 2B(y-y_1)(x-x_1) + C(x-x_1)^2$$
$$+2(Ay_1 + Bx_1 + D)(y-y_1) + 2(By_1 + Cx_1 + E)(x-x_1)$$
$$+Ay_1^2 + 2Bx_1y_1 + Cx_1^2 + 2Dy_1 + 2Ex_1 + F = o,$$

and in virtue of equation (2) this becomes

$$(Am^2 + 2Bm + C)(x-x_1)^2 + 2(D'm+E')(x-x_1) + F = o \ldots (b);$$

where, for the sake of brevity, we assume

$$Ay_1 + Bx_1 + D = D', By_1 + Cx_1 + E = E' \quad \ldots\ldots\ldots\ldots\ldots (c),$$
$$Ay_1^2 + 2Bx_1y_1 + Cx_1^2 + 2Dy_1 + 2Ex_1 + F = F' \quad \ldots\ldots (d).$$

By eliminating $x-x$ from equations (a) and (b), we obtain

$$\frac{Am^2 + 2Bm + C}{m^2 + 2m\cos\gamma + 1} R^2 + \frac{2(D'm+E')}{\sqrt{(m^2 + 2m\cos\gamma + 1)}} R + F' = o \ldots (e),$$

the roots of which are the segments AP_1 and AP_2 (Fig. 2) of the straight line (2) intercepted between the point x_1y_1 and the two points in which it cuts the curve (1).

(a.) By a well-known property of quadratics, we obtain from equation (e)

$$AP_1 . AP_2 = \frac{F'(m^2 + 2m\cos\gamma + 1)}{Am^2 + 2Bm + C} \ldots\ldots\ldots\ldots\ldots\ldots (3),$$

which evidently holds good, whether the points P_1 and P_2 be real or imaginary.

(β.) When the direction-index m of the straight line (2) satisfies the condition

$$Am^2 + 2Bm + C = o \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4),$$

equation (e) gives $R = \dfrac{F'\sqrt{(1 + 2m\cos\gamma + m^2)}}{2(D'm + E')}$ $\ldots\ldots\ldots (5)$;

consequently, in this case, the straight line (2) can meet the curve (1) in only one point.

II.

When $D'm + E' = o$, the middle term of equation (e) will vanish, and the roots of that equation will be equal with opposite signs. Hence, in this case, A must be the middle point of the chord $P_1 P_2$. Now, when m is constant, or the chord $P_1 P_2$ is parallel to a given straight line $y=m\,x$, it is evident, from equations (c), that $D'm+E'=o$ is the condition that the middle point $x_1\, y_1$ of the chord $P_1 P_2$ may be on the straight line

$$(Ay+Bx+D)\,m+(By+Cx+E)=o\ldots\ldots\ldots\ldots\ldots(6).$$

Hence we see that *the line* (6) *is the locus of the points of bisection of all chords of the curve* (1), *which are parallel to the straight line* y=m x.

The straight line (6) which bisects chords parallel to the line $y=m\,x$, is called a *diameter* of the curve (1), and any chord (2) which is bisected by the diameter (6), is called an *ordinate* to that diameter.

(α.) When the ordinates are parallel to the axis of x we have $m=o$, and equation (6) becomes

$$By+Cx+E=o\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7),$$

which is, therefore, the equation to the diameter that bisects chords parallel to the axis of x.

(β.) When $m=\infty$, equation (6) gives

$$Ay+Bx+D=o\ \ldots\ldots\ldots\ldots\ldots\ldots(8);$$

this is, therefore, the equation of the diameter which bisects chords parallel to the axis of y.

(γ.) It is evident from the form of equation (6) that every diameter of the curve (1) passes through the point of intersection of the straight lines (7) and (8.) On account of this remarkable property the intersection of these lines is called the *centre* of the curve (1.) Let x_2 and y_2 denote the co-ordinates of the centre, then since the point $x_2\, y_2$ is on each of the straight lines (7) and (8), we shall have

$$Ay_2+Bx_2+D=o,\ By_2+Cx_2+E=o,$$

from which we obtain by elimination

$$x_2=\frac{AE-BD}{B-AC},\ y_2=\frac{CD-BE}{B^2-AC}\ldots\ldots\ldots\ldots(9.)$$

These equations indicate a very simple method of finding the centre of a curve represented by any given equation of the second degree.

(δ.) Since every chord of the curve (1) which passes through its centre is an ordinate to some particular diameter, it is evident that *every chord which passes through the centre is bisected at the centre.*

(ϵ.) If $B^2=AC$, while BD is not equal to AE, it is evident from equations (9) that the centre of the curve (1) passes to infinity. In this case it is usual to say that the curve has no centre. Hence arises a division of curves of the second degree into two classes. 1st. The *central class,* characterized by the condition B^2 not equal to AC. 2nd. The *non-central* class, characterized by the condition $B^2=AC$.

(ζ.) By multiplying equation (6) by B, we obtain

$$(Am+B)\,By+(B^2m+BC)\,x+B\,(Dm+E)=o.$$

Now when the curve (1) belongs to the non-central class this equation may be written in the form

$$(Am+B)\,(By+Cx)+B\,(Dm+E)=o \quad\ldots\ldots\ldots\ldots(10),$$

from which we see that *all the diameters of a non-central curve of the second degree are parallel to the diameter*

$$By+Cx=o. \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10')$$

which passes through the origin of co-ordinates.

III.

In a curve of the second degree, any diameter which is perpendicular to its ordinates is called an *axis* of the curve. Hence if m' and m denote the direction indices of an axis and its ordinate respectively, we shall have

$$1+(m+m')\cos\gamma+m\,m'=o\ldots\ldots\ldots\ldots\ldots(a),$$

γ being the angle made by the positive axes of x and y. Now (a) in the case of a non-central curve we have $m'=-C:B$ (by eq. 10), and therefore equation (a) becomes

$$B+(Bm-C)\cos\gamma-m\,C=o,$$

which gives $m=\dfrac{C\ \cos\gamma-B}{B\ \cos\gamma-C}=\dfrac{B\cos\gamma-A}{A\cos\gamma-B}$

for the direction-index of the ordinates to the axis. Substituting this value of m in equation (10), we obtain, after slight reductions,

$$\{(A+C)\cos\gamma - 2B\}(By+Cx)+(BD+CE)\cos\gamma$$
$$-(CD+BE)=o \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11),$$

which is the equation to the axis of the curve (1) when equation (1) represents a non-central curve.

(β.) In the case of a central curve, since m' is the direction index of the straight line (4), we have

$$A\,m\,m' + B\,(m+m') + C = o;$$

hence, by eliminating m by means of equation (a), we get

$$(A\cos\gamma - B)\,m'^{\,2}+(A-C)\,m' = C\cos\gamma - B \ldots\ldots\ldots(b.)$$

Solving this by the common rule for quadratics, we have

$$m' = \frac{C - A \pm \sqrt{\{(A-C)^2 + 4\,(B - C\cos\gamma)(B - A\cos\gamma)\}}}{2\,(A\cos\gamma - B.)}\,.$$

Now, since the suffix of the radical in this equation may be written in the form,

$$(A-C)^2(\sin^2\gamma+\cos^2\gamma) + 4B^2 - 4B(A+C)\cos\gamma + 4AC\cos^2\gamma,$$
$$\text{or } \{(A-C)\sin\gamma\}^2 + \{2B - (A+C)\cos\gamma\}^2,$$

it follows that the roots of equation (b) are always real; and thus we see that *every central curve of the second degree has two axes, and cannot have more than two.*

IV.

Returning to the general formula in No. II, let the point A coincide with the centre C of the curve (1), the straight line (2) cutting the curve in P and Q (fig. 3); then by equation (3) we shall have

$$CP.\,CQ = \frac{F''\,(m^2 + 2\,m\cos\gamma + 1)}{A\,m^2 + 2\,B\,m + C}\,,$$

where $F'' = Ay_2^{\,2} + 2\,B\,y_2\,x_2 + C\,x_2^{\,2} + 2\,D\,y_2 + 2\,E\,x_2 + F$,
$\quad = D\,y_2 + E\,x_2 + F$ (by No. II),

and the values of x_2 and y_2 are given by equations (9). But since PQ is bisected in C, we have $CQ = -CP$, and the preceding equation gives

$$CP = \sqrt{\frac{-F''(m^2+2m\cos\gamma+1)}{Am^2+2Bm+C}} \ldots\ldots\ldots\ldots\ldots (12).$$

(*a*.) The factor $m^2+2m\cos\gamma+1$ in the numerator of the fraction under the radical sign in this equation is always positive, since it is equal to

$$(m+\cos\gamma)^2+(\sin\gamma)^2,$$

and consequently the numerator has the same sign as $-F.''$ The denominator admits of the form

$$A\left\{\left(m+\frac{B}{A}\right)^2+\frac{AC-B^2}{A^2}\right\},$$

and therefore when $B^2 < AC$ the denominator has the same sign as A and can never vanish. Hence, since A is supposed to be positive, No. I., when $-F''$ is positive the value of CP given by eq. (12) is real and finite for all values of m, and the curve (1) is an oval limited in every direction; but when F'' is positive CP is imaginary and the equation has no locus. In the former case the curve is called an ellipse, and thus we see that the conditions in order that the equation (1) may represent an ellipse are that B^2 be less than AC and F'' negative.

(β.) When $B^2 > AC$ the roots of the equation $Am^2+2Bm+C=0$ are real. If m' and m'' denote these roots it is evident from equation (12) that the lines CS and CT (Fig. 4) whose equations are

$$y-y_2=m'(x-x_2) \text{ and } y-y_2=m''(x-x_2)$$

meet the curve (1) in four points at infinity. The infinite diameters SCS′ and TCT′ of a curve of the second degree are called the *asymptotes* of the curve. Hence we see that for any curve (1) of the second degree, the direction indices of the asymptotes are the roots of the quadratic equation

$$Am^2+2Bm+C=0 \ldots\ldots\ldots\ldots (13).$$

By a well known property of quadratics,

$$Am^2+2Bm+C=A(m-m')(m-m'').$$

Now when m is intermediate between m' and m'', one of the factors $m-m'$ and $m-m''$ is positive and the other negative, and consequently the denominator of the fraction under the radical sign in equation (12) has the same sign as $-A$; but for all other values of m the factors have like signs, and therefore the denominator has the same sign as $+A$. Hence we see, that when F'' has the same sign as A, the central radius vector CP is real for all values of m between m' and m'' and imaginary for all others, or that the curve (1) is included within the angles S C T and S′ C T′; and that when $-F''$ has the same sign as A, CP is imaginary for all values of m between m' and m'' and real for all others, or the curve is included in the angles S C T′ and S′ C T. In both cases the curve is called a *hyperbola*, and therefore the equation (1) always represents a hyperbola when $B^2 > AC$, provided that F'' be finite.

(γ.) When the curve (1) belongs to the non-central class it is called a *parabola;* hence (II) the conditions in order that the equation (1) may represent a parabola are $B^2 = AC$ and BD not equal to AE.

(δ.) When $C = A$ and $B = A \cos \gamma$ equation (12) becomes

$$CP = \sqrt{-F'' : A},$$

and consequently when F'' and A have unlike signs, the curve (1) is a circle, but when F'' and A have like signs the locus is imaginary. Hence equation (1) will represent a circle when $C = A$ and $B = A \cos \gamma$, provided that F'' be negative.

V.

We have seen (No. 1) that the equation

$$Am^2 + 2\,Bm + C = 0 \ldots\ldots\ldots\ldots (a)$$

expresses the condition that the straight line (2) may meet the curve (1) in only one point. Now (a) when $B^2 > AC$ the curve is a hyperbola, and the roots of this equation are the direction-indices of its asymptotes (IV); hence, *if from any point two straight lines be drawn parallel to the asymptotes of a hyperbola, each of these lines will cut the curve in only one point.*

(β.) When $B^2=AC$ the roots of equation (a) are equal and the value of each is $-B:A$; hence, we see that *the only straight line which can be drawn from a given point so as to cut a parabola only in one point is the diameter which passes through the given point.*

(γ.) When $B^2<AC$ the roots of (a) are imaginary; and therefore *no straight line can be drawn in the plane of an ellipse so as to cut it in only one point.*

VI.

If the straight line (2) meet the curve (1) in the points P_1 and P_2 = we have seen (I.) that

$$AP_1 . AP_2 = \frac{F'(m^2+2m\cos\gamma+1)}{Am^2+2Bm+C}.$$

Let $Q_1 Q_2$ (Fig. 5) be a chord parallel to $P_1 P_2$, and passing through the origin of co-ordinates O; then, since F' becomes F when A coincides with O, we shall have

$$OQ_1 . OQ_2 = \frac{F(m^2+2m\cos\gamma+1)}{Am^2+2Bm+C};$$

and by dividing the former equation by the latter we obtain

$$\frac{AP_1 . AP_2}{OQ_1 . OQ_2} = \frac{F'}{F} \text{..............(a)}$$

Similarly, if P_3P_4 and Q_3Q_4 be another pair of parallel chords, passing through A and O respectively, we shall have

$$\frac{AP_3 . AP_4}{OQ_3 . OQ_4} = \frac{F'}{F},$$

and by comparing this with the last equation we get

$$\frac{AP_1 . AP_2}{AP_3 . AP_4} = \frac{OQ_1 . OQ_2}{OQ_3 . OQ_4}. \text{ ....(14).}$$

Hence *if two chords of a curve of the second degree be drawn intersecting each other, the rectangle contained by the segments of the one will have an invariable ratio to the rectangle contained by the segments of the other, provided that each of the chords always remains parallel to a given straight line.*

(a.) When the line OQ_3 meets the curve (1) in only one point, (Fig. 6.) it is evident (v.) that AP_3 will meet it only in one point. In this case we shall have (I.)

$$AP_3 = \frac{-F'\sqrt{(m_1^2+2m_1\cos\gamma+1)}}{2(D'm_1+E')},\ OQ_3 = \frac{-F\sqrt{(m_1^2+2m_1\cos\gamma+1)}}{2(Dm_1+E)};$$

m_1 being the direction index of OQ_3 or AP_3. Hence if we assume

$$D'm_1+E' = Dm_1+E \ldots\ldots\ldots\ldots\ldots \text{(b)},$$

we shall have $F.AP_3 = F.'OQ_3$; and by comparing this with equation (a) we get

$$\frac{AP_1.AP_2}{AP_3} = \frac{OQ_1.OQ_2}{OQ_3} \ldots\ldots\ldots\ldots (15).$$

Substituting for D' and E' their values given in No. I., the condition (b) becomes

$$(Am_1+B)\,y_1+(Bm_1+C)\,x_1 = 0 \ldots\ldots\ldots \text{(b}'\text{)},$$

and this must be combined with the equation

$$Am_1^2 + 2Bm_1 + C = 0,$$

which expresses the condition that OQ_3 should meet the curve in only one point (No. I). From the latter equation we obtain

$$m_1 = \frac{-B \pm \sqrt{(B^2-AC)}}{A} = \frac{-B \pm B'}{A} \text{ suppose,}$$

and by substituting this in equation (b′), we get, after slight reductions

$$B'\{Ay_1 + (B \mp B')\,x_1\} = 0 \ldots\ldots\ldots\ldots\ldots \text{(c)}.$$

Now, when $B'=0$ this equation is satisfied independently of x_1 and y_1, and therefore *when the curve* (1) *is a parabola the equation* (15) *holds good for every possible position of the point A;* but when the curve (1) is a hyperbola, B' is finite, and the equation (c) cannot be satisfied unless x_1 and y_1 fulfil the condition.

$$Ay_1+(B \pm B')\,x_1 = 0.$$

Hence we see that, in this case, *the relation* (15) *will not hold* *good unless the point A be on a straight line drawn through* O *parallel to one of the asymptotes,* in which case the points P_3 and Q_3 coincide.

VII.

Let us now consider the case in which the curve (1) is a parabola. Let P_1 P_2 (Fig. 6) be an ordinate to the diameter AP_3, then since $AP_1=AP_2$ (II), equation (15) gives

$$\frac{AP_1^2}{AP_3}=\frac{OQ_1.OQ_2}{OQ_3}=p' \text{ suppose};$$

hence, if $AP_3=x$, $AP_1=y$, we shall have

$$y^2=p'x \ldots\ldots\ldots\ldots(16)$$

for the equation of the parabola referred to any diameter AQ_3 and the line drawn through Q_3 parallel to its ordinates, as axes of co-ordinates.

(α.) The quantity p' evidently remains invariable for the same diameter, and is called the *parameter* of that diameter. To find a general expression for p', we have (I)

$$OQ_1.OQ_2=\frac{F(m^2+2m\cos\gamma+1)}{Am^2+2Bm+C},$$

$$OQ_3=\frac{-F\surd(m_1^2+2m_1\cos\gamma+1)}{2(Dm_1+E)}$$

$$=\frac{-F\surd(B^2-2BC\cos\gamma+C^2)}{2(BE-CD)}, \text{ since } m_1=-\frac{C}{B}.$$

$$\therefore\ p'=\frac{2(CD-BE)(m^2+2m\cos\gamma+1)}{(Am^2+2Bm+C)\surd(B^2-2BC\cos\gamma+C^2)}\ldots(17),$$

m being the direction index of the ordinates to the diameter AP_3.

(β.) The vertex P_3 of the diameter AP_3 may be determined from the simultaneous equations (1) and (10.) Combining these with the equation $B^2=AC$, we obtain, by eliminating C and y, and then eliminating A and x,

$$\left.\begin{aligned} x&=\frac{AF-D^2}{2(BD-AE)}+\frac{BD-AE}{2(Am+B)^2} \\ y&=\frac{CF-E^2}{2(BE-CD)}+\frac{(BE-CD)m^2}{2(Bm+C)^2} \end{aligned}\right\}\ldots\ldots(18),$$

which determine the origin of the new co-ordinates introduced in equation (16.)

(γ.) When equation (1) represents a parabola we are now prepared to determine the *elements* which fix its position in relation to the original axes of co-ordinates. The simplest elements that can be employed for this purpose appear to be the co-ordinates of its principal vertex (α, β), the direction-index of its axis (μ,) and its principal parameter (π). Now, by No. II. we have

$$\mu = -C : B = -B : A,$$

and the values of π, α, β will be obtained from the last three equations by taking

$$m = \frac{C \cos\gamma - B}{B \cos\gamma - C} = \frac{B \cos\gamma - A}{A \cos\gamma - B}, \text{ (III)}.$$

Thus, after some easy reductions, we get

$$\pi = \frac{2\,(A^{\frac{1}{2}}E - C^{\frac{1}{2}}D) \sin^2\gamma}{(A + C - 2\,B \cos\gamma)^{\frac{3}{2}}} \ldots\ldots\text{(19)},$$

$$\left.\begin{aligned} \alpha &= \frac{AF - D^2}{2(BD - AE)} + \frac{BD - AE}{2\,A^2}\left(\frac{B - A\cos\gamma}{A + C - 2\,B\cos\gamma}\right)^2 \\ \beta &= \frac{CF - E^2}{2(BE - CD)} + \frac{BE - CD}{2\,C^2}\left(\frac{B - C\cos\gamma}{A + C - 2\,B\cos\gamma}\right)^2 \end{aligned}\right\}\ldots\text{(20)}.$$

VIII.

It is evident from No. II. that the equations

$$(A\,y + B\,x + D)\,m + (B\,y + C\,x + E) = o \ldots\ldots\ldots\ldots\text{(a)},$$

$$(A\,y + B\,x + D)\,m' + B\,y + C\,x + E = o \ldots\ldots\ldots\ldots\text{(b)},$$

denote the diameters of the curve (1) which bisect chords parallel to the straight lines $y = m'\,x$ and $y = m\,x$ respectively. Now the condition that the diameter (b) should be parallel to the straight line $y = m\,x$ is

$$A\,m\,m' + B\,(m + m') + C = o \ldots\ldots\ldots\ldots\ldots\ldots\text{(21)}$$

and this is also the condition that the diameter (a) should be parallel to $y = m'x$; hence we see that *if two diameters* (a) *and* (b) *be so related that the first* (a) *bisects all chords parallel to the second* (b), *then the second will bisect all* *chords parallel to the first.* On account of this remarkable property the diameters (a) and (b) are said to be *conjugate* to each other when their direction-indices satisfy the condition (21).

(α.) If $2a'$ and $2b'$ denote the lengths of the two conjugate diameters whose equations are (b) and (a), we shall have (IV. 12)

$$a'^2 = \frac{-F''(m^2+2m\cos\gamma+1)}{Am^2+2Bm+C} \quad \text{.........(c)},$$

$$b'^2 = \frac{-F''(m'^2+2m'\cos\gamma+1}{Am^2+2Bm'+C} \quad \text{.........(d)},$$

where m and m' are subject to the condition (21).

(β.) By taking the product of eqns. *(c)* and *(d)* we get

$$a'^2.b'^2 = \frac{F''^2(m^2+2m\cos\gamma+1)\ (m'^2+2m'\cos\gamma+1)}{(Am^2+2Bm+C)\ \ (Am^2+2Bm'+C)} \quad \text{.......(e)},$$

and by subtracting the square of the first member of equation (21) from the denominator of the fraction in its second member this equation becomes

$$a'^2\ b'^2 = \frac{F''^2(m^2+2m\cos\gamma+1)\ (m'^2+2m'\cos\gamma+1)}{(AC-B^2)\ (m'-m)^2}.$$

Again, if δ denote the inclination of the conjugate diameters *(a)* and *(b)*, we obtain, by the theory of the straight line,

$$\sin^2\delta = \frac{(m'-m)^2\sin^2\gamma}{(m^2+2m\cos\gamma+1)\ (m'^2+2m'\cos\gamma+1)};$$

hence, by taking the product of the last two equations, we have

$$a'^2\ b'^2\sin^2\delta = F''.^2\sin^2\gamma : (AC-B^2),$$

$$\text{or } a'\ b'\sin\delta = F''\sin\gamma\ (AC-B^2)^{-\frac{1}{2}} \text{......(22)}.$$

The second member of this equation is real or imaginary according as B^2 is less or greater than AC; hence *when the curve* (1) *is an ellipse any two conjugate semidiameters are both real, but when it is a hyperbola, of any two conjugate semidiameters one is always real and the other imaginary.*

(γ.) Since $a'.\ b'.\sin\delta$ denotes the area of a parallelogram having two adjacent sides equal to a', b', and the contained angle equal to δ, it follows from equation (22) that *the area of* *the parallelogram contained by any two conjugate semi-diameters of an ellipse or hyperbola is invariable;* being equal to $F'' \sin\gamma\,(AC-B^2)^{-\frac{1}{2}}$ when the curve is an ellipse, and to $F'' \sin\gamma\,(B^2-AC)^{-\frac{1}{2}}$ when it is a hyperbola.

(δ.) From equations *(c)* and *(d)* we readily obtain

$$\frac{a'^2+b'^2}{-F''}=\frac{\begin{array}{c}(m^2+2\,m\cos\gamma+1)\,(A\,m'^2+2\,B\,m'+C)\\+\,(m'^2+2\,m'\cos\gamma+1)\,(A\,m^2+2\,Bm+C)\end{array}}{A\,m^2+2\,B\,m+C)\,(A'm'^2+2\,B\,m'+C)}\;\ldots\ldots(f).$$

Now we have just seen that the denominator of the fraction in the second member is equal to$-(B^2-AC)\,(m'-m)^2$, and by subtracting the first member of equation (21) multiplied by $2+2\,m\,m'$ from the numerator, it becomes

$$(A+C)\,(m'-m)^2+2\cos\gamma\,\{(A\,m\,m'+C)\,(m'+m)+4\,B\,m'\,m\},$$

which in virtue of equation (21) easily reduces to

$$(A+C-2\,B\cos\gamma)\,(m'-m)^2.$$

Hence, by substituting these reduced expressions for the numerator and denominator in equation (f), we obtain

$$a'^2+b'^2=F''\,(A+C-2\,B\cos\gamma)\,(B^2-AC)^{-1}\ldots\ldots(23).$$

When the curve (1) is an ellipse a'^2 and b'^2 are both positive, but when it is a hyperbola one of them is positive and the other negative. Hence equation (23) shows that, *in an ellipse, the sum, and in a hyperbola, the difference of the squares of any two conjugate diameters is invariable.*

(ϵ.) We are now prepared to determine the lengths a' and b' of two conjugate semi-diameters which shall contain a given angle δ. For, since by equations (22) and (23) we have

$$\frac{a'^2+b'^2}{F''}=\frac{A+C-2\,B\cos\gamma}{B^2-AC},$$

$$\frac{a'^2.b'^2}{F''^2}=\frac{-\sin^2\gamma}{(B^2-AC)\sin^2\delta};$$

it follows that if z_1 and z_2 denote the roots of the quadratic equation,

$$(B^2-AC)\,z^2-(A+C-2\,B\cos\gamma)\,z-\sin^2\gamma.\,\sin^{-2}\delta\ldots(24),$$

we shall have

$$a'^2=F''z_1\;,\;b'^2=F''z_2\ldots\ldots\ldots\ldots\ldots\ldots(25).$$

(ζ.) When two conjugate diameters are at right angles to each other, it is evident, from the definition in No. III., that each of them is an axis of the curve. Hence if a and b denote the semi-axes of the curve (1), we shall have (ϵ),

$$a^2 = F''z_1,\ b^2 = F''z_2 \dots\dots\dots\dots\dots\dots (26)$$

where z_1 and z_2 are the roots of the equation

$$(B^2 - AC)z^2 - (A + C - 2B\cos\gamma)z - \sin^2\gamma = o \dots\dots (27).$$

This simple rule determines the magnitude and form of the central curve represented by any equation of the second degree; and the position of the curve in reference to the original axes of co-ordinates may be found by means of equation *(b)*, No. III.

(η.) When $F'' = o$, it is evident from equations (26) that the semi-axes of the curve (1) are both zero; from which we see, that, if the curve be of the elliptic species, it must vanish in this case into a point; but, if it be of the hyperbolic species, it must coincide with its asymptotes. Hence, when $B^2 < AC$ and $F'' = o$, the locus of equation (1) is a point; but when $B^2 > AC$ and $F'' = o$, the locus breaks up into two straight lines. This remark completes the discussion of central curves given in No. IV.

IX.

Let ACA' and BCB' (Fig. 7 and 8) be any system of conjugate diameters of the curve (1), PP' any line parallel to the latter and meeting the former in Q; then, by the theorem in No. IV., we shall have

$$PQ.QP' : AQ.QA' :: BC.CB' : AC.CA', \text{ or}$$

$$PQ^2 : AQ.QA' :: BC^2 : AC^2 \dots\dots\dots\dots\dots\dots (28)$$

(a.) Let $CA = a'$, $CB = b'$, $CQ = x$, $QP = y$; then, if the curve be an ellipse, we obtain from (28)

$$y^2 : (a' + x)(a' - x) :: b'^2 : a'^2,$$

but if it be a hyperbola we have

$$y^2 : (x + a')(x - a') :: b'^2 : a'^2;$$

hence, after slight reductions, we get,

$$\text{for the ellipse, } \frac{x^2}{a'^2}+\frac{y^2}{b'^2}=1 \ldots\ldots\ldots (29),$$

$$\text{for the hyperbola, } \frac{x^2}{a'^2}-\frac{y^2}{b'^2}=1 \ldots\ldots\ldots (30).$$

These, therefore, are the equations to the ellipse and hyperbola, referred to any system of conjugate diameters as axes of co-ordinates.

(β.) Taking now A as the origin of co-ordinates, let $AQ=x$, $QP=y$, be the co-ordinates of P; then, for the ellipse, equation (28) gives

$$y^2 : x\,(2a'-x) :: b'^2 : a'^2, \text{ or}$$

$$y^2=\frac{b'^2}{a'^2}(2a'x-x^2) \ldots\ldots\ldots\ldots (31);$$

but, when the curve is a hyperbola, we have

$$y^2 : x\,(2a'+x) :: b'^2 : a'^2, \text{ or}$$

$$y^2=\frac{b'^2}{a'^2}(a2'x+x^2) \ldots\ldots\ldots\ldots (32).$$

Equations (31) and (32) are the equations to an ellipse and hyperbola, referred to any diameter and a line drawn through its extremity parallel to its ordinates as axes of co-ordinates. The values of the constants a' and b' which occur in the last four equations are given by equations (c) and (d) of No. VIII.

X.

Returning to equation (e) of No. I., it is evident that when the co-ordinates $x_1\, y_1$ of the point A satisfy the conditions

$$F'=o,\ D'm+E'=o \ldots\ldots\ldots\ldots\ldots\ldots (a),$$

each of the roots of equation (e) will be zero, and consequently the straight line (2) will be a tangent to the curve (1). The former condition, $F'=o$, merely implies that the point A should be on the curve (1). From the latter we obtain $m=-E' : D'$, which substituted in equation (2) gives

$$D'(y-y_1)+E'(x-x_1)=o \ldots\ldots\ldots\ldots (b)$$

for the equation of the tangent applied to the curve (1) at the point $x_1\, y_1$. From equation (b) we readily deduce

$$D'y+E'x+Dy_1+Ex_1+F=(D'+D)y_1+(E'+E)x_1+F=F'=o,$$

$$\text{or } (Ay_1+Bx_1+D)y+(By_1+Cx_1+E)x$$
$$+Dy_1+Ex_1+F=o\ldots\ldots\ldots\ldots(33),$$

which is a simpler form of the equation to the tangent applied to the curve (1) at the point $x_1 y_1$.

(α.) The equation $D'm+E'=o$ may also be considered as the condition that the straight line (b) may pass through the point $x_1\ y_1$; and therefore it determines the direction-index m of the ordinates to the diameter of the curve (1) which passes through a given point A. Hence we see that *the tangent applied to any curve of the second degree at a point* A *is parallel to the ordinates of the diameter which passes through that point.*

(β.) Let two straight lines be drawn from a fixed point $x_1 y_1$ touching the curve (1) at the points $x'y'$ and $x''y''$ respectively; then, since each of these tangents passes through the point $x_1 y_1$, we shall have, by equation (33),

$$(Ay'+Bx'+D)y_1+(By'+Cx'+E)x_1+Dy'+Ex'+F=o,$$
$$(Ay''+Bx''+D)y_1+(By''+Cx''+E)x_1+Dy''+Ex''+F=o.$$

But these are also the conditions that the points $x'\ y'$ and $x''\ y''$ may be on the straight line

$$(Ay_1+Bx_1+D)y+(By_1+Cx_1+E)x+Dy_1+Ex_1+F=o\ldots(34);$$

hence it is evident that *the straight line* (34) *is the chord of contact of two tangents drawn to the curve* (1) *from the given point* $x_1 y_1$.

(γ.) If $x\ y$ be the point of intersection of any two tangents to the curve (1), and $x_1 y_1$ any fixed point in the chord of contact, we shall have, by equation (34),

$$(Ay+Bx+D)y_1+(By+Cx+E)x_1+Dy+Ex+F=o,$$

which can also be written in the form

$$(Ay_1+Bx_1+D)y+(By_1+Cx_1+E)x+Dy_1+Ex_1+F=o\ldots(35).$$

Hence we see that, *if any chord of the curve* (1) *be drawn through the fixed point* $x_1 y_1$, *and tangents be applied to the curve at its extremities, the locus of the intersection of the tangents is the straight line* (35).

XI.

We have seen (VI. a) that if AO be a line parallel to an asymptote of a hyperbola, cutting the curve in P_3, and the two parallel chords $P_1 P_2$ and $Q_1 Q_2$ in A and O respectively, we shall have

$$AP_1 . AP_2 : OQ_1 . OQ_2 :: AP_3 : OP_3.$$

Now, when AO coincides with an asymptote, AP_3 and OP_3 become infinite, and may evidently be considered as equal. Hence we see that, if any chord $P_1 P_2$ of a hyperbola be drawn parallel to a given straight line, and produced if necessary to meet an asymptote in A, *the rectangle contained by the segments into which the chord is cut by the asymptote is invariable.*

(a.) When A coincides with the centre C of the hyperbola, the points P_1 and P_2 may be real or imaginary, but the rectangle $CP_1 . CP_2$ is real, and equal to

$$-F''(m^2 + 2m\cos\gamma + 1) : (Am^2 + 2Bm + C), \text{ (IV)},$$

where m is the direction-index of $P_1 P_2$. Hence (VIII. a) the rectangle $AP_1 . AP_2$ is equal to the square of the semidiameter which is parallel to $P_1 P_2$.

(β.) If $P_1 P_2$ be produced to meet the other asymptote in A′, we shall have (a).

$$AP_1 . AP_2 = A'P_1 . A'P_2,$$

since each of these rectangles is equal to the square of the semidiameter parallel to $P_1 P_2$. From this equation it is evident that $AP_1 = A'P_2$, and thus we see that *if any straight line be drawn cutting a hyperbola and its asymptotes, the segments intercepted between the curve and its asymptotes shall be equal.*

(γ.) When the chord $P_1 P_2$ becomes a tangent, the points P_1 and P_2 coalesce in a point of contact P, and $AP_1 . AP_2$ becomes equal to AP^2. Hence (a) *if any tangent be applied to a hyperbola and produced to meet the asymptotes, the part of the tangent intercepted between the asymptotes is equal to* *the diameter of the hyperbola which is parallel to it, and that portion of the tangent is bisected at the point of contact.*

(δ.) Since the diameter of a hyperbola which passes through the point of contact is conjugate to the diameter which is parallel to the tangent (X.a), it follows from the properties (γ) that *the area of the triangle contained by any tangent and the asymptotes, is equal to the area of the parallelogram contained by the system of conjugate semidiameters one of which is parallel to the tangent and the other passes through the point of contact.* Hence the area of the triangle in question is the same for every tangent, and equal to

$$F'' \sin\gamma\,(B^2 - AC)^{-\frac{1}{2}},\ (\text{XI. }\gamma).$$

(ϵ.) If straight lines be drawn from the point of contact P parallel to the asymptotes, the area of the parallelogram CP formed by these lines and the asymptotes will evidently be half the area of the triangle formed by the tangent and the asymptotes. Hence, denoting the parallels by x and y, we have (δ)

$$xy \sin\theta = \tfrac{1}{2} F'' \sin\gamma\,(B^2 - AC)^{-\frac{1}{2}},$$

where θ denotes the angle contained by the asymptotes. If, for the sake of brevity, we assume

$$c^2 = \tfrac{1}{2} F'' \sin\gamma\,(\sin\theta)^{-1}\,(B^2 - AC)^{-\frac{1}{2}} \ldots\ldots.(\text{a}),$$

the last equation becomes

$$xy = \tfrac{1}{4} c^2 \ldots\ldots\ldots\ldots\ldots(36),$$

which is the equation of the hyperbola referred to its asymptotes as axes of co-ordinates.

(ζ.) Let m' and m'' denote the direction-indices of the asymptotes, then by the theory of the straight line

$$\tan\theta = \frac{(m' - m'')\sin\gamma}{1 + m'\,m'' + (m' + m'')\cos\gamma}.$$

Now since m' and m'' are the roots of the equation

$$Am^2 + 2\,Bm + C = o,\ (\text{IV. }\beta),$$

we shall have $A\,(m' + m'') + 2\,B = o$, $Am'\,m'' - C = o$,

and $A\,(m' - m'') = 2\sqrt{(B^2 - AC)}$;

$$\therefore \tan\theta = \frac{2\sin\gamma\sqrt{(B^2-AC)}}{A+C-2B\cos\gamma} \ldots\ldots (37).$$

From this equation we readily deduce

$$\frac{\sin\theta}{\sin\gamma} = \frac{2\sqrt{(B^2-AC)}}{\sqrt{(A+C-2B\cos\gamma)^2+4(B^2-AC)\sin^2\gamma}},$$

and by substituting this in equation (a) we get

$$c^2 = \frac{F''}{B^2-AC}\sqrt{\left\{(A+C-2B\cos\gamma)^2+4(B^2-AC)\sin^2\gamma\right\}} (38).$$

The constant c, determined by this equation, is sometimes called the *power* of the hyperbola.

XII.

Any point $x_1\, y_1$ being given in the plane of the curve (1), the straight line whose equation is

$$(Ay_1+Bx_1+D)y+(By_1+Cx_1+E)x+Dy_1+Ex_1+F=o \ldots (39)$$

is called the *polar* of the point $x_1\, y_1$ in relation to the curve (1), and the point $x_1\, y_1$ is called the *pole* of the straight line (39). From these definitions the following theorems are immediately obvious.

(α.) When the pole is on the curve (1), the polar passes through the pole and touches the curve at that point, (X).

(β.) When the pole is without the curve, the polar is the chord of contact of the two tangents drawn from the pole to the curve (X, β).

(γ.) When the pole is within the curve, the polar is the locus of the intersection of two tangents applied to the curve at the extremities of any chord passing through the pole. This is also true when the pole is on the curve (1) or outside of it (X. γ).

(δ.) When the pole is at the centre of the curve (1),

$$Ay_1 + Bx_1 + D=o,\ By_1 + Cx_1 + E=o,\ (\text{II}, \gamma),$$

and the equation of the polar becomes, (IV),

$$o.\, y+o.\, x+F''=o;$$

hence when the pole is at the centre of the curve the polar is at infinity.

(ϵ.) When the pole is at the origin of co-ordinates we have $x_1 = o$, $y_1 = o$, and the equation of the polar becomes

$$Dy + Ex + F = o \ldots\ldots\ldots\ldots (40).$$

(ζ.) If the co-ordinates of the pole satisfy the equations,

$$By_1 + Cx_1 + E = o, \; Dy_1 + Ex_1 + F = o \ldots\ldots (a),$$

equation (39) becomes $y = o$, and the polar is the axis of x. Hence equations (a) determine the pole of the axis of x.

(η.) If the co-ordinates of the pole satisfy the equations

$$Ay_1 + Bx_1 + D = o, \; Dy_1 + Ex_1 + F = o \ldots\ldots (b),$$

the polar is the axis of y, and therefore equations (b) determine the pole of the axis of y.

XIII.

Let x_1 y_1 denote the co-ordinates of the pole of the straight line

$$y = mx + h \ldots\ldots\ldots\ldots (a);$$

then, since the polar of the point x_1 y_1 is

$$(Ay_1 + Bx_1 + D)y + (By_1 + Cx_1 + E)x + Dy_1 + Ex_1 + F = o, \text{(b)},$$

the straight lines (a) and (b) are identical, and we have

$$(Ay_1 + Bx_1 + D)\, m + By_1 + Cx_1 + E = o \ldots\ldots (41),$$

$$(Ay_1 + Bx_1 + D)\, h + Dy_1 + Ex_1 + F = o \ldots\ldots (42).$$

(α.) When m and h are given constants, these equations enable us to find the pole x_1 y_1 of the straight line (a).

(β.) When m is constant and h variable, equation (a) denotes a series of lines parallel to the straight line $y = m\,x$; and equation (41) shows that the pole of any of these lines lies on the diameter

$$(Ay + Bx + D)\, m + By + Cx + E = o.$$

Hence *if a system of straight lines be drawn in the plane of a curve of the second degree parallel to a given line, the locus of their poles is the diameter which bisects chords parallel to that line.*

(γ.) Let equation (a) denote a system of straight lines passing through a given point x' y', then

$$y' = m\,x' + h,$$

and by substituting the values of m and h given by equations (41) and (42) this equation becomes

$$(Ay_1+Bx_1+D)y'+(By_1+Cx_1+E)x'+Dy_1+Ex_1+F=o,$$

which is the condition that the point $x_1\,y_1$ may be on the straight line

$$(Ay'+Bx'+D)\,y+(By'+Cx'+E)\,x+Dy'+Ex'+F=o.$$

Hence *if a system of straight lines* (a) *pass through a given point* $(x'\ y')$, *the locus of their poles is the polar of that point.*

(δ.) Conversely, *if any number of points lie on a straight line, their polars intersect in the pole of that line.*

Let the equation to the straight line be

$$y=m\,x+h\ldots\ldots\ldots\ldots\text{(c)},$$

and let $x_1\,y_1$ be any point on this line, so that

$$y_1=m\,x_1+h\ldots\ldots\ldots\ldots\text{(d)};$$

then since the polar of $x_1\,y_1$ is, (XII),

$$(Ay_1+Bx_1+D)y+(By_1+Cx_1+E)x+Dy_1+Ex_1+F=o,$$

we obtain by eliminating y_1,

$$\{(Ay+Bx+D)\,m+By+Cx+E\}x_1,$$
$$+(Ay+Bx+D)\,h+Dy+Ex+F=o.$$

Now when $x_1\,y_1$ is *any* point on the straight line (c), x_1 will be indeterminate, and the last equation shows that the polar of any point on the straight line (c) must pass through the intersection of the straight lines

$$\left.\begin{array}{l}(Ay+Bx+D)\,m+By+Cx+E=o\\(Ay+Bx+D)\,h+Dy+Ex+F=o\end{array}\right\}\ldots\ldots\ldots\text{(e)},$$

which, by equations (41) and (42), is the pole of the straight line (c).

XIV.

The forms of the principal curves represented by the general equation (1) have been investigated in No. IV., and to complete the discussion there given we may now consider the case in which $B^2=AC$, and $BD=AE$. In this case we have $BE=CD$, and the values of x_2 and y_2 given by equations

(9) assume the indeterminate form $\frac{o}{o}$. Multiplying equation (7) by B we obtain

$$B^2 y + BCx + BE = o,$$

and in virtue of the preceding conditions this becomes

$$Ay + Bx + D = o \text{.................(a)};$$

hence equations (7) and (8) are identical in this case, and any point in the straight line (a) may be considered as the centre of the locus.

By multiplying equation (1) by A, we obtain, in this case,

$$A^2 y^2 + 2ABxy + B^2 x^2 + 2ADy + 2BDx + AF = o,$$

$$\text{or } (Ay + Bx)^2 + 2D(Ay + Bx) + AF = o,$$

$$\text{and } \therefore \quad Ay + Bx = -D \pm \sqrt{(D^2 - AF)} \text{.........(b)};$$

hence when $D^2 > AF$ the locus is two straight lines (b) parallel to the line (a), when $D^2 = AF$ the locus is the straight line (a), and when $D^2 < AF$ the locus is imaginary.

The loci which can be represented by the general equation (1) may now be enumerated as follows:—

Central Class.

(α.) If $C = A$, and $B = A \cos \gamma$, the locus is a circle (IV., δ).

(β.) If $B^2 < AC$ and $F'' < o$, the locus is an ellipse (IV., α).

(γ.) If $B^2 < AC$ and $F'' = o$, the locus is a point (VIII., η).

(δ.) If $B^2 < AC$ and $F'' > o$, the locus is imaginary (IV., α).

(ϵ.) If $B^2 > AC$ and F'' not $= o$, the locus is a hyperbola (IV., β).

(ζ.) If $B^2 > AC$ and $F'' = o$, the locus is two straight lines cutting one another (VIII., η).

(η.) If $B^2 = AC$, $BD = AE$, and $D^2 > AF$, the locus is two parallel straight lines (XIV).

(θ.) If $B^2 = AC$, $BD = AE$, and $D^2 = AF$, the locus is one straight line (XIV).

(ι.) If $B^2 = AC$, $BD = AE$, $D^2 < AF$, the locus is imaginary (XIV).

Noncentral Class.

If $B^2 = AC$ and BD not $= AE$, the locus is a parabola (IV., γ).

XV.

Hitherto our attention has been chiefly directed to the most general form (1) of the equation of the second degree, but in many cases the equation becomes simplified in form by the evanescence of one or more of its co-efficients A, B, C, &c. Some of the simplest of these forms have been given in Nos. VII., IX., XI., and we now proceed to point out a few others.

(α.) When the curve (1) passes through the origin of co-ordinates its equation must be satisfied by the simultaneous equations $x=o$ and $y=o$; hence we shall have $F=o$, and equation (1) takes the form

$$Ay^2 + 2\,Bxy + Cx^2 + 2\,Dy + 2\,Ex = o \text{.........(a)}.$$

(β.) When $E=o$ the diameter (7) which bisects chords parallel to the axis of x passes through the origin; hence when the origin is on the diameter which bisects chords parallel to the axis of x equation (1) takes the form

$$Ay^2 + 2\,Bxy + Cx^2 + 2\,Dy + F = o \text{.........(b)}.$$

Similarly, when the origin is on the diameter which bisects chords parallel to the axis of y, equation (1) becomes

$$Ay^2 + 2\,Bxy + Cx^2 + 2\,Ex + F = o \text{.........(c)}.$$

When the origin is at the centre we have $D=o$, $E=o$, and the equation becomes

$$Ay^2 + 2\,Bxy + Cx^2 + F = o \text{.........(d)}.$$

(γ.) When $B=o$ equations (7) and (8) become

$$Cx+E=o \text{ and } Ay+D=o,$$

and therefore the diameters which bisect chords parallel to the axes of x and y are respectively parallel to the axes of y and x. Hence, when the axes are parallel to a system of conjugate diameters, equation (1) takes the form

$$Ay^2 + Cx^2 + 2\,Dy + 2\,Ex + F = o \text{.........(e)}.$$

When the curve (1) is a parabola the condition $B=o$ gives $A=o$ or $C=o$.

(δ.) When $C=o$ equation (13) gives $m=o$, and therefore the curve (1) has an asymptote parallel to the axis of x.

Hence, when the axis of x is parallel to an asymptote, equation (1) becomes

$$Ay^2 + 2Bxy + 2Dy + 2Ex + F = o \text{......(f).}$$

Similarly, when the axis of y is parallel to an asymptote, the equation takes the form

$$2Bxy + Cx^2 + 2Dy + 2Ex + F = o \text{......(g),}$$

and when both the axes are parallel to the asymptotes, the equation becomes

$$2Bxy + 2Dy + 2Ex + F = o \text{.........(h).}$$

IV.—*On the Origin and Nature of the Forces that produce Storms.* By Mr. Alderman Hopkins.

[*Read December 16th,* 1851.]

Storms are strong winds, differing in degree and not in nature, from ordinary winds or moderate breezes. All the great movements of the atmosphere have their origin in vertical currents which are produced by certain known causes. These currents are fed from less or greater distances by horizontal currents, which press and flow towards the area of ascent, and the horizontal currents, whether they appear as moderate winds or storms, are thus produced by the ascending currents. These latter currents are created by the aqueous vapour which is intermixed with the gases of the atmosphere, heating these gases, through the process of condensation, thus causing them to expand into a larger space, and to press with less weight than they had previously done on the surface of the earth. The adjoining colder, and therefore heavier atmospheric gases then rush under and force the warmer and lighter to ascend in the form of vertical currents, and the heavier gases, being themselves successively heated by the condensation of their vapour, also rise, when more air presses towards the ascending mass, and thus, these processes being repeated and continued, a Wind or a Storm may be produced.

But it has been said by persons who object to the hypothesis here advanced, that the heat liberated in the atmosphere by the condensation of aqueous vapour, is not sufficient to lighten the air in the locality, to an extent that shall create a rapidly ascending current. That much latent heat is however really given out and made sensible, raising the temperature in the part where vapour is converted into water, is well known and universally admitted. It is familiarly experienced when steam is condensed in our steam engines, and I have explained it more fully in papers formerly read to this Society.

It is not however often that the whole of the vapour that is in the atmosphere is condensed into water, or even so much of it as there commonly is in the condensor of the steam engine, seeing that the heat liberated in the atmosphere warms the part and the air that is in it, and thus stops or checks the condensation that is taking place. And it is not until the gases are made lighter through being warmed, and that the remaining vapour which is mingled with them is carried successively to greater elevations, that the whole or nearly the whole of the vapour existing in any locality is condensed.

When dry air, that is, air entirely without vapour, is taken to a height of, say one hundred yards, the expansion that is consequent on the diminished incumbent pressure at that height, cools it say 1° Fahrenheit; but if the air be saturated with vapour, some portion of the vapour will be condensed by the cold produced through expansion of the air, and the result will be that the mixed mass of air and vapour will be found to be cooled, not to the full degree of dry air belonging to the elevation, but only to about one half of it; the warming influence of condensation of a part of the vapour having counteracted the cooling effect of expansion of the gases, to the extent of the other half. The mixed mass being however half a degree warmer than the adjoining cold air, is forced up in the atmospheric space by the colder and heavier air. On reaching the height of two hundred yards, incumbent atmospheric pressure is sufficiently reduced to cool pure air 2°, but condensation of vapour counteracts this cooling to the extent of one half, as just explained, and the result is that the actual cooling of the mixed mass is only 1° instead of 2°. This double process being continued to greater heights in the atmosphere, the absolute cooling of the ascending mass is only half a degree for every hundred yards of height.

The facts here stated may be proved by pumping out air that has been deprived of vapour from the receiver of an air pump, until expansion of the air within takes place to an extent equal to that which occurs, on air being removed from the surface of the earth to the height of one hundred yards in the atmosphere, when, as we have seen, the temperature sinks 1°. But if the air in the receiver be saturated with vapour, some of the vapour will be condensed by the cold of expansion, and then the temperature of the mixture will be found to be reduced only about half a degree. It follows from this experiment that, in an atmospheric column that is ascending to higher regions, and in which condensation of vapour is taking place, the heat liberated reduces the cooling to about one half of what it would otherwise be; and two adjoining masses or atmospheric columns of the height of, say four thousand eight hundred yards, the one undisturbed by condensation, and the other having condensation going on within it, would have the temperatures as put down in the following table at the heights named, the dew-point and temperature at the surface of the earth being supposed to be both at 80° :—

Yards high.	Clear air.	Clouded air.	Difference.
4,800	32°	56°	24°
4,000	40°	60°	20°
3,000	50°	65°	15°
2,000	60°	70°	10°
1,000	70°	75°	5°
0	80°	80°	0°

Now it is evident that in the part of the atmosphere which is, say one thousand yards high, the clear air of the temperature of 70° and of the density and weight which belong to that temperature, will have a tendency to press under and force up the adjoining column that has the higher temperature of 75°, and which is therefore proportionately lighter; and the heavier column will press up the lighter with a force equal to the difference in the weights of the two, which is expressed in the numbers of the table by 5° of temperature. At the height of two thousand yards the difference of temperature in the two adjoining columns is 10°, and consequently the clear air at this height will have a tendency to press up the recently clouded air with a force expressed by the 10°. At three thousand yards high the superior weight of the clear air is 15°, and at four thousand eight hundred yards, when the freezing point in the clear air is reached, the difference in the two columns is no less than 24°. Thus we see, that on condensation taking place in any particular part of the atmosphere where the temperature and dew-point at the surface were at 80°, it would make that part so light as to permit it to be forced up by the adjoining heavier air at an increasing velocity, expressed by the numbers in the table which indicate the differences of the temperatures at the various heights. The commencement of this process would be slow, like the first movement of a railway carriage by a steam engine, but the velocity of the ascending current would increase with the difference of the temperatures of the two columns, until the aqueous vapour, the material furnishing the moving power, was exhausted. And as the velocity of the ascending current increased, so would the quantity of air that ascended within it increase; and the greater that increase the larger would be the quantity of the atmosphere that would press from adjoining parts, to fill the comparative vacuum that had been made by the condensation of the vapour. Here then we see, that under the circumstances described, a very energetic expanding power comes into action in the atmosphere, which reduces the weight of the air in the locality, whilst the adjoining heavier air that then presses and rushes in successively to fill the comparative vacuum, must produce a horizontal movement of air or a wind, the force and rapidity of which will be proportioned to the degree of vacuum created.

In the table that has been given, we have exhibited the cooling of the atmosphere through reduction of incumbent pressures, as it may be presumed to take place in a tropical region, to the height of only four thousand eight hundred yards, because, in air that was undisturbed by condensation, the temperature of 32° or the freezing point was then attained. But there is no reason that an ascending current heated by condensation as it proceeded, and pressed upwards by fresh air rushing from below, should stop in its ascent when it had reached the height of four thousand eight hundred yards. On the contrary, the tendency of such a current when supplied with sufficient vapour, which becomes lighter through being warmed, is to permit its being raised to far greater heights, and the difference in the temperature of the two adjoining columns of clear and of clouded air, as long as condensation was proceeding, would still be the measure of power with which the heavier column would force up the lighter. In the following table this difference is shewn up to a height of ten thousand yards :—

Yards high.	Clear air.	Clouded air.	Difference.
10,000	—20°	30°	50°
9,000	—10°	35°	45°
8,000	0°	40°	40°
7,000	10°	45°	35°
6,000	20°	50°	30°
5,000	30°	55°	25°
4,000	40°	60°	20°
3,000	50°	65°	15°
2,000	60°	70°	10°
1,000	70°	75°	5°
0	80°	80°	0°

Here we see that at the height of ten thousand yards from the surface of the earth, the difference of temperature between the clear and the clouded atmospheric columns produced by condensation of vapour, is no less than 50°; and with a force proportioned to that difference would the former column be disposed to press up the latter, whilst the pressure upwards at the various intermediate heights would be as the numbers expressing the difference of temperature.

So far we have treated of the condensation of vapour carrying high temperature to great elevations; but at a certain stage of the process a new power comes into action. The undisturbed atmosphere was presumed to be of a lower temperature than 32°, above the height of four thousand eight hundred yards; any vapour, therefore, ascending above that height and entering the cold air that existed there, would be liable to be not only condensed into water, but to be frozen into snow! And were it not for the heat that is liberated by condensation, the vapour that penetrated this lofty region would be not only condensed, but frozen. And further, although condensation liberates much heat and keeps the temperature in the ascending column above the freezing point to a considerable height, yet at some greater elevation that point will be reached even within the comparatively warm ascending column. When this takes place and freezing commences within the column, we have a result differing from that which has been pointed out, as a new law then comes into operation.

When, through reduction of incumbent pressure, the ascending mass cools down to a temperature below 32°, the particles of water that had been formed by condensation are frozen; and in freezing, the liquid water gives out the latent heat that is always liberated when water is converted into ice. Now this liberated heat will have a tendency to keep up the temperature of the ascending column, and of the water and ice that are in it, and to prevent that temperature from falling below 32°. For it is well known that when a body of water is frozen by a moderate degree of cold, the process of freezing is slow, as the conversion of a part of the liquid into ice liberates heat enough to preserve the remainder in the form of water; and it requires time for the liberated heat to pass away before a fresh portion of the water can be frozen by the existing degree of cold in the locality. In this way a mixed mass of water and ice may remain a considerable time at the temperature of 32°, in a part that is below that temperature, the heat given out to the water by freezing being nearly equal to that which is passing away; and this comparatively slow operation continues until all the water is frozen. The same process must take place in the atmosphere, when the particles of water produced by condensation of vapour are frozen into snow or hail, that is into ice. As the ice is formed the heat of liquidity of the water is set free, and the temperature of the locality and of the substances that are in it, is prevented sinking below 32° until all the water in the part is frozen. It follows from this, that when an ascending atmospheric column takes newly formed water that is within it to a height sufficient to freeze the water, the column for some time retains the temperature of 32°, while it is ascending successively into colder regions. The respective temperatures of the undisturbed cold air in the vicinity, and of the warmed ascending column that is passing through it, may, under these circumstances, be as shewn in the following table, commencing from the temperature of zero at the surface; whilst the differences between the temperatures of the two airs would be those which are inserted in the tabular column of the differences:—

Yards high.	Clear air.	Clouded air.	Difference.
10,000	—100°	32°	132°
9,000	—90°	32°	122°
8,000	—80°	32°	112°
7,000	—70°	32°	102°
6,000	—60°	32°	92°
5,000	—50°	32°	82°
4,000	—40°	32°	72°
3,000	—30°	32°	62°
2,000	—20°	32°	52°
1,000	—10°	32°	42°
0	0°	32°	32°

It will be observed that in this table we presume that in clear and undisturbed air the temperature at the surface is at zero, which is found only in very cold localities; and as the temperature is presumed to be lower after the rate of 1° for every one hundred yards of ascent, at the height of ten thousand yards it will be 100° below zero. But as we presume that the heat liberated by condensation and freezing, as just explained, keeps the column in which these processes are taking place for some time at 32°, the difference between the two columns at the full height named must be for that time 132°. In so very cold a locality as that of which we are now treating, we know that any vapour which escaped from the surface of the earth and passed into the atmosphere, would be soon condensed; but the heat that would then be liberated would keep the product of that condensation in a liquid state for some certain time, however short it might be, yet in such a part that heat would pass rapidly away, and the liquid would be frozen. The liberated heat of liquidity would, however, now preserve the cloud of liquid and frozen particles for some further time at 32°; and then two processes, first, condensation of vapour, and secondly, congelation of water, being successively and rapidly repeated in a column ascending to a great height, would keep the whole mass at

32°, as long as vapour remained to be condensed and frozen. And thus we find that the difference in the temperature of the two adjoining parts indicated in the table, would be established for some time, however short it might be.

It has been often observed that, when the temperature near the surface of the earth has been greatly below the freezing point, upon a fall of snow occurring, the temperature has suddenly risen to 32°; and it commonly remains there as long as the snow continues falling. Now it is known that this snow often descends from a considerable height in the atmosphere, and it is to be presumed that it brings the air, which is found to have a temperature of 32°, down with it. The same fact is frequently observable in high latitudes, where the cold is intense. However low the surface temperature may have previously been, on a considerable quantity of snow falling it shews a tendency to rise to 32°. Such changes near the surface indicate, that in the part of the atmosphere in which the snow was formed from floating particles of water, whatever might be the height, the temperature in that part could not be below 32°.

It is not necessary to suppose that in cold latitudes, under the circumstances described, vapour shall be actually carried up to so great a height as ten thousand yards, or to any other particular height approaching it; but what has been observed in those latitudes gives reason to believe, that snow and spiculae of ice are there formed from vapour at greater elevations than has been hitherto imagined. Our object at present however is, not to shew precisely what occurs in such lofty regions, but to explain the kind of laws that govern the atmospheric changes that take place in them, and to point out that to whatever extent these changes do occur, they must be under the control of the laws that have been exhibited.

In high latitudes, where the cold is intense, but little vapour is found in the atmosphere, and therefore great and extensive atmospheric disturbances seldom take place in those parts; but in the tropical regions, where vapour is more abundant, the phenomena that have been under consideration are often exhibited in energetic action over a wide extent. It is probably at an elevation that gives a temperature below the freezing point, even in the warmed ascending currents, that the fierce storms of the tropics generally take place; and where those storms are very violent in their character, the probability is that condensation of vapour and freezing of water are successively carried to a great height in the atmosphere, although the commencement of the former of these processes may have been in the middle, or even in the lower regions. With a temperature and dew-point of 80° at the surface, in an undisturbed atmosphere, we have seen that the freezing point is reached at a height of four thousand eight hundred yards; but in a fierce tropical storm the vapour from the lower regions may be carried very far above that height. The comparative vacuum formed by a heated ascending current, which had a dew-point of 80° at the surface, and which is successively supplied from below with equally saturated air, may produce an ascent of not merely four thousand eight hundred yards, but of ten thousand yards or more. And in portions of the column the current must be rapid as well as continuous, taking a large amount of vapour from the lower to the higher regions, where its congelation as well as its condensation may finally produce those great differences of temperature in adjoining parts of the atmosphere that have been pointed out.

It is obvious that an ascending column extending over a considerable area, or in other words, having a large horizontal diameter, being lighter than contiguous undisturbed air, will press with proportionately less weight on the surface of the earth on which it rests; and a barometer placed in such a part, would, by the falling of the mercury, measure the diminution of pressure. The degree, however, of that diminution in any particular part, will depend not solely on the amount of vapour condensed, and consequently of air heated, but also on the height in the atmosphere at which these changes take place. With a given amount of vapour condensed, the nearer to the earth that the condensation occurs, the greater will be the reduction of pressure on any particular point of its surface, and the farther from the earth, the less the reduction of pressure on any particular part. Hence it follows that in the polar regions, where the cold of the surface is intense, condensation of a small quantity of vapour produces a greater effect on the mercury of the barometer than it does in the warm tropical regions. In the latter regions the base of the column of warmed air may be at a considerable height, and the total reduced pressure of that base may be spread over a large area of the surface of the earth, and may consequently affect each particular part of that surface in but a small degree: whilst in the former regions the base of the warm column may be close to the earth, and the reduction of pressure may therefore be limited to a small area, within which however the pressure might be greatly reduced.

Air is expanded by heat, say a 480th part of its bulk, for every increase of 1° of temperature, and consequently it will be expanded one-tenth part by an increase of 48° of temperature. It follows therefore that where an ascending mixed mass of air and vapour reaches a mean temperature of 48°, above that of the undisturbed part at the same elevation, the ascending mass would be one-tenth lighter than the adjoining part, a difference equal to the weight of three inches of mercury, and sufficient to cause the heavier to press up the lighter air with great force. On the whole it is contended, that if an adequate portion of aqueous vapour be supplied to any ascending mass of the atmosphere, the laws of cooling of the gases by expansion, and of heating them through condensation and congelation of vapours, that are known to exist, when traced in their operations extending into the higher parts of the atmosphere, are capable of producing disturbances of a very energetic character, such as those attending hail and thunder storms. And it is submitted, that the causes which have been here traced are fully adequate to the production of all the effects that are experienced in strong winds or fierce storms.

V.—*Contributions to the Knowledge of the Manufacture of Gas.*

By E. Frankland, Ph.D., F.C.S., *Professor of Chemistry at Owens College.*

The importance of the manufacture of gas for illuminating purposes must be admitted by all, and artificial light thus procured has become almost a necessary of life; yet it is remarkable how little progress has been made in this branch of art, since the first few years of its existence. It is true that so far as the mechanical part of the process is concerned, considerable improvements have been effected, and by the application of new methods of purification, we are now enabled to free the gas from almost every objectionable ingredient, yet, although the generation of luminiferous gas depends essentially upon chemical principles, as it is the modification of the force of affinity by the agency of heat that determines the products of every destructive distillation, it is impossible carefully to peruse the results of the late Dr. Henry's beautiful and elaborate researches on this subject, without being forcibly struck by the comparatively slight advance which has been made in what I may be allowed to call the generating department of gas-making, since that distinguished philosopher applied himself to its investigation. Better descriptions of coal and some new materials have been tried and have come into use; the disengagement of the gas has been facilitated by decreasing the pressure within the retorts; and attempts have been made to increase the proportion of luminiferous ingredients, by regulating the heat so as to make it most favourable for their development; but no *new principle* has been applied to the generating process, and although the attempts above alluded to have been attended with some success, yet it is evident from Dr. Henry's description of the quantity and quality of gases obtained from coal and cannel, which was laid before this society in 1819, that little has been gained either as regards the quantity of gas obtainable from a given weight of coal or its illuminating power. Our knowledge of the constituents of coal gas has also been very little extended, although our means of gaseous investigation have been greatly increased by the labours of Bunsen, Kolbe, Regnault and others, in perfecting the methods employed in the analysis of gases.

Under these circumstances, I venture to hope that the observations contained in the following pages, imperfect as they are in many respects, may not be altogether unacceptable as contributions to our present knowledge of this very important branch of manufactures. These observations derive their origin from an extensive series of experiments just concluded, which I made at the request of two merchants of this town, upon a new process of gas manufacture known as White's Hydrocarbon process, of which I believe the members of this society are not entirely ignorant. In detailing these experiments and the conclusions arising from them, I shall endeavour as much as possible to eschew the commercial relations of the subject, and confine myself to points of a strictly scientific character.

The usual process of gas-making consists, as is well known, in exposing coal or cannel to a red heat in close vessels of convenient size and shape, until all, or the greater part of the volatile matter is expelled. Coke is the material left in the retort, and the matters volatilized consist of condensible vapours, and permanent gases more or less saturated with these vapours. It does not appear that the quantity of coke obtained from a given weight of coal is liable to any important increase or diminution, from any variation of temperature between the limits that are usually employed in gas-making, but the relative amount and also the quality of the liquid and gaseous products, depend very considerably upon the temperature to which the materials are exposed in the retorts. As a general rule, the lower the heat the more do the liquid products increase at the expense of the gaseous ones; whilst the higher the heat the greater is the yield in gas, the quantity of the liquids being at the same time diminished; but not only does the relative quantity of the gas produced thus vary, its quality also depends essentially upon the heat employed, that produced at low temperatures being usually superior to that evolved at higher ones.

The gas thus generated contains several constituents which require to be removed, before it is fit for use as a light-giving material; but it is not my intention at present to discuss the methods used in the purification of gas, or indeed to describe more minutely the usual processes of manufacture, since these have been so fully and clearly delineated in an excellent paper read before the society last year by Mr. Leigh; I therefore confine myself to some general observations upon the relative value of the constituents of coal or other gas, to considerations respecting the quantity and quality of the purified gas obtainable from the materials in general use, and the methods by which both the one and the other may be increased.

The constituents of purified gas are hydrogen, light carburetted hydrogen, carbonic oxide, olefiant and other gases, having the general formula $C_n H_n$, the vapours of hydrocarbons having the formula $C_n H_n$ and $C_n H_{(n-6)}$, and other hydrocarbons whose formulæ are unknown: in addition to these, coal gas usually contains small quantities of nitrogen, oxygen, and bisulphuret of carbon vapour; but, for our present purpose, these may be entirely disregarded.

It has always been maintained that hydrogen and carbonic oxide possess no illuminating power, and that the light emitted by coal gas is due to the light carburetted hydrogen, olefiant gas, and other hydrocarbons. I hope, however, to prove by the experiments detailed below, that, for all practical purposes, light carburetted hydrogen is also entirely devoid of illuminating power, and that therefore, the whole of the light-giving effect is due to the olefiant gas and hydrocarbons. This is an important point, as we shall find that it much simplifies the estimation of the illuminating power of any sample of gas, and teaches us that the nature of the combustible diluents of the olefiant gas and hydrocarbons, has no effect whatever upon the quantity of light emitted by the mixture.

The constituents of coal and other gases may be divided into two classes, viz., illuminating and non-illuminating constituents; to the first will belong olefiant gas and the other hydrocarbons above mentioned, and to the second, light carburetted hydrogen, hydrogen and carbonic oxide. To the first class alone the illuminating power of the gas is due, but some member of the second class is also indispensable as a diluent, without which we should find great difficulty in consuming the hydrocarbons, without the production of much smoke and consequent loss of light. The members of the first class are all decomposed instantaneously at a white heat, at a red heat more slowly, depositing the whole or the greater part of their carbon in the form of very fine particles, which become so many centres for the radiation of light in the gas flame, and the greater the number of particles existing in any flame at the same moment, the greater will be the light emitted by that flame. It is therefore evident that the value of these hydrocarbons for the production of light, depends directly upon the quantity of carbon contained in a given volume, and is altogether independent of the hydrogen with which this carbon is combined; consequently, the densest or most easily condensible of these gases and vapours of the first class, are those which possess the highest illuminating power. All the compounds belonging to this class are, as before stated, decomposed more or less rapidly at a red heat, and in the ordinary process of gas-making, the interior walls of the retorts soon become coated with a stratum of carbon derived from this source. Now the extent of this decomposition must depend, first, upon the length of time during which they are exposed to the heated materials, and secondly, upon the number of particles which are in contact with the red hot surface, consequently it will be diminished, first, by removing the gases rapidly from the retort, and secondly, by the mixture of the illuminating constituents with the non-illuminating ones; for it is evident that the number of particles of olefiant gas in contact with a *given surface*, would only be half so great if this gas were diluted with an equal volume of hydrogen, as it would be without such an admixture.

Besides the use that has already been mentioned of the second class or non-illuminating gases, they are of value as forming a medium for the solution of the vapours of such hydrocarbons as exist in the liquid or even solid state at the ordinary temperature of the atmosphere, and they thus enable us to convert an additional quantity of illuminating materials into the gaseous form, which they retain permanently unless the temperature fall below the point of saturation. The gain in illuminating power which is thus obtained will be perhaps better seen from the following example:—Suppose 100 cubic inches of olefiant gas, allowed to saturate itself with the vapour of a volatile hydrocarbon, containing three times as much carbon in a given volume of its vapour as that contained in an equal volume of olefiant gas, took up or dissolved three cubic inches of this vapour, then, if we express the value of 1 cubic inch of olefiant gas by unity, the illuminating power of the 103 cubic inches of the mixture of olefiant gas and hydrocarbon vapour will be 109. Now if we mix these 103 cubic inches with 100 cubic inches of hydrogen, the mixture will be able to take up an additional three cubic inches of hydrocarbon vapour, and the illuminating power of the 206 cubic inches will then become 118; thus the hydrogen produces a gain in illuminating power equal to 9 cubic inches of olefiant gas, or nearly 4·5 per cent. upon the volume of mixed gases. When we consider that coal naptha contains hydrocarbons of great volatility, and that these are the surplus remaining after the saturation of the gas from which they have condensed, the importance of this function of the non-illuminating class of combustible gases will be sufficiently evident. I may here remark that incombustible gases could not be employed for this purpose, since their cooling influence upon the flame during the subsequent burning of the gas, would diminish the light to a far greater extent than the hydrocarbon vapour could increase it.

It is evident that all the three non-illuminating gases forming the second class, would perform both the offices I have assigned to them perfectly well, and therefore we have as yet seen no reason for giving our preference in favour of any one of these diluents; if, however, we study their behaviour during combustion, we shall find that where the gas is to be used for illuminating purposes, hydrogen has qualities which give it a very decided preference over the other two. When gas is used for lighting the interior of public buildings and private houses, it is very desirable that it should deteriorate the air as little as possible, or in other words, it should consume as small a quantity of oxygen, and generate as little carbonic acid as possible; and the oppressive heat which is so frequently felt in apartments lighted with gas will also be admitted by all to show the advantage of that gas generating a minimum amount of heat.

The following is a comparison of the properties of the three non-illuminating gases, in reference to the points just mentioned:—

1 cubic foot of light carburetted hydrogen, at 60°F. and

30in. barometrical pressure, consumes 2 cubic feet of oxygen during its combustion, and generates 1 cubic foot of carbonic acid, yielding a quantity of heat capable of heating 5lbs. 14oz. of water from 32° to 212°, or causing a rise of temperature from 60° to 80·8° in a room containing 2,500 cubic feet of air.

1 cubic foot of carbonic oxide at the same temperature and pressure, consumes during combustion ½ a cubic foot of oxygen, generates one cubic foot of carbonic acid, and affords heat capable of raising the temperature of 1lb. 14oz. of water from 32° to 212°, or that of 2,500 cubic feet of air from 60° to 66·6°.

1 cubic foot of hydrogen at the same temperature and pressure consumes ½ a cubic foot of oxygen, generates no carbonic acid, and yields heat capable of raising the temperature of 1lb. 13oz. of water from 32° to 212°, or that of 2,500 cubic feet of air from 60° to 66·4°.

This comparison shows that light carburetted hydrogen is very objectionable as a diluent, not only on account of the carbonic acid which it generates, but also by reason of the very large quantity of oxygen which it consumes, and the very great amount of heat which, in relation to its volume, it evolves on combustion, the consumption of oxygen being four times and the absolute thermal effect more than three times as great as that of either of the other gases.

The quantity of heat evolved by the combustion of equal volumes of carbonic oxide and hydrogen, is nearly, and the amount of oxygen consumed quite the same, but the carbonic acid evolved from the first gives a decided preference to hydrogen as the best diluent.

The same comparison also shows that when the gas is to be used for heating purposes, and the products of combustion are carried away, light carburetted hydrogen is by far the best diluent.

The experiments of Dulong on the absolute thermal effect of hydrogen, light carburetted hydrogen, and carbonic oxide, are taken as the basis of the foregoing calculations. Dulong found that—

1 lb. H	raised the temperature of	1 lb. HO	through	62471°F.
1 lb. CO	" "	1 lb.	"	4504°F.
1 lb. CH_2	" "	1 lb.	"	24244°F.

These considerations indicate the objects that should chiefly be regarded, in the generating department of the manufacture of gas for illuminating purposes. They are—

1st. The extraction of the largest possible amount of illuminating compounds from a given weight of material.

2nd. The formation of a due proportion of illuminating and non-illuminating constituents, so that on the one hand the combustion of the gas shall be perfect, and without the production of smoke or unpleasant odour, and on the other the volume of gas required to procure a certain amount of light shall not be too large.

3rd. The presence of the largest possible proportion of hydrogen amongst the non-illuminating constituents, to the exclusion of light carburetted hydrogen and carbonic oxide, so as to produce the least amount of heat and atmospheric deterioration in the apartments in which the gas is consumed.

I have not introduced these preliminary remarks to show the inductive reasoning by which the process of gas-making described below was arrived at, for I believe that, so far as the above considerations are concerned, that process was accidentally adopted; but I bring them forward to illustrate and explain the results of the following experiments, and also to show that a close study of the chemistry of gas-manufacture would have led to the discovery of this more philosophical method of gas-generation long ago.

Mr. White's process consists essentially in the generation of non-illuminating combustible gases by the action of steam upon charcoal, coke, or other deoxidizing substances, in a separate retort, and the introduction of these gases, along with an excess of watery vapour, into the retort in which the illuminating gases are being generated, and in such a manner that these latter gases shall be swept out of the retort as rapidly as possible, and thus removed from the destructive influence of a high temperature.

The excess of steam accompanying the water gas into the second retort performs there a remarkable office; it reacts upon the tar and other fuliginous matter in a manner that will be described below, and gives rise to the formation of a large additional quantity of gas, a very large proportion of which is pure hydrogen. That this reaction of steam should be confined entirely to the tar and other refuse matters, and should not affect the luminiferous gases generated in the same retort, is scarcely conceivable, since the constitution of tar and of gaseous hydrocarbons is so nearly alike; but any destruction of illuminating principles that may be thus caused, is immensely overbalanced by the quantity of these principles which are saved from decomposition, by their rapid removal from the influence of a high temperature and by the vapours of volatile hydrocarbons with which the water gases remain more or less saturated.

My first experiments were made upon the application of the process to resin; but as these are of less scientific interest than those on its application to coals and cannels, on account of there having been no comparative experiments on resin gas produced by the old process, I will confine myself principally to a summary of the results, entering into detail only on such points as bear upon, and illustrate the principles which I have laid down.

WHITE'S PROCESS APPLIED TO RESIN.

These experiments were conducted at the gas works attached to the mill of Messrs. George Clarke and Co., Ancoats, Manchester. These works consisted, at that time, of a bench containing two resin-gas retorts and two water-gas retorts of the largest size. The water retorts discharged themselves into the resin retorts, and these last worked into a hydraulic main, from which the gas passed successively through a refrigerator and wet lime purifier to the gas holder, a vessel of the ordinary construction, and capable of containing about 18,000 cubic feet.

The volume of gas produced was measured by a meter placed between the last purifier and the holder; a copper for melting the resin, and an oil cistern for collecting the residual oil condensed in the hydraulic main and refrigerator during the process, completed the apparatus.

Before commencing each experiment, the quantity of gas in the holder was carefully determined, and a specimen withdrawn for analysis; the charcoal retorts were then filled, the resin melted in the oil of a former working—about 7½ gallons being used for each 112lbs. of resin,—and the water and oil tanks being first accurately gauged, the process of gas-making was commenced by admitting properly regulated streams of resin and water into their respective retorts.

The temperature of the gas, as it passed through the meter, was found never to exceed 60°F., and was frequently much below this point, thus affording a sufficient guarantee for the correctness of the numbers read off.

The specimens of gas were drawn from the holder on the morning following each experiment, in order to insure perfect mixture and a fair sample; and the analyses of these gases, as well as those examined in the experiments upon coals and cannels, were made over mercury, according to methods which I have fully detailed in the Journal of the Chemical Society, (vol. ii. p. 269, June, 1849,) with this difference, that a new form of apparatus was employed, which will be elsewhere described. This instrument much shortens the processes, without rendering them less accurate. The volume of the gases was always read off when they were saturated with watery vapour; the proper correction was afterwards made for this, and the per centage numbers given in the following analysis invariably refer to the gases free from watery vapour. The carbonic acid was determined by caustic potash, the oxygen by Liebig's new method, viz., by absorption with a solution of pyrogallic acid in caustic potash, the illuminating hydrocarbons by strongly fuming sulphuric acid, and the rest of the gases by explosion with excess of oxygen, in which the amount of oxygen consumed and carbonic acid generated were estimated, and the respective volumes of light carburetted hydrogen, carbonic oxide, hydrogen and nitrogen, calculated from the numbers thus obtained.

Various attempts have been made to estimate the illuminating power of coal and other gases from the analytical results yielded by them, but hitherto no certain method of accomplishing this has been established. Dr. Henry regarded the consumption of oxygen by a given volume of the gas to be a rough estimate of its illuminating power; but it is evident that although generally those gases which have the highest illuminating power consume the largest amount of oxygen in relation to their volume, yet this is not always the case, for a gas containing 10 per cent. of olefiant gas, 20 per cent. of light carburetted hydrogen, and 70 per cent. of hydrogen, would consume much less oxygen during combustion than one containing only 5 per cent. of olefiant gas, and in which the proportions of light carburetted hydrogen and hydrogen were reversed, although the illuminating power of the former would be twice as great.

It will be seen, from what has already been said respecting the illuminating power of hydrocarbons, that the more dense these bodies are the greater is the amount of light they yield. This important fact was first pointed out by Mr. Leigh, who was also the first to make a near approach towards accurately estimating the illuminating power of gas from its analysis. Mr. Leigh regards the illuminating power of coal gas as being due to hydrocarbons and light carburetted hydrogen, and the value of the former as being directly proportionate to the quantity of oxygen required for their combustion. If we leave the light carburetted hydrogen entirely out of the calculation, as I shall prove that this gas has practically no illuminating power, this method generally gives results not far from the truth; but they are, nevertheless, liable to very considerable error from the fact that the amount of oxygen consumed does not depend alone upon the luminiferous ingredient—the carbon, but also upon the amount of hydrogen combined with that element, and which is necessarily a variable quantity, being in some of the hydrocarbons in the ratio C : H = n : n, in others C : H = n : n—6, and in some C : H = n : n—12. In order to avoid this source of error, and obtain a correct expression for the illuminating power, however much the composition of the hydrocarbon may vary, I have estimated the volume of carbon vapour contained in the luminiferous hydrocarbons, and made that the basis of the calculation. I have already pointed out a method for this estimation of the carbon vapour;* and Mr. Leigh, in a memoir lately read before this society,† also describes a similar plan, which he employs for the determination of the consumption of oxygen by these bodies. The following is the mode of procedure which I have employed in the annexed determinations of the value of various hydrocarbons.

A known quantity of the gas, previous to the action of fuming sulphuric acid, is exploded with an excess of oxygen, and the volume of carbonic acid produced accurately noted. Another known volume of the same gas, after the withdrawal of the hydrocarbons by sulphuric acid, is then similarly exploded with oxygen, and the carbonic acid formed also estimated. Thus, there are determined—1st, The per centage

* Journal of the Chem. Soc., vol. ii. p. 272. 1849.

† Mem. of the Lit. and Phil. Soc. of Manchester, vol. ix., p. 303. 1851.

amount of hydrocarbons; 2nd, The volume of carbonic acid generated by hydrocarbons, plus the volume of the same gas produced by the non-luminiferous gases; and 3rd, The volume of carbonic acid generated by the non-luminous gases alone. From these data it is easy to calculate the amount of carbonic acid generated by one volume of the hydrocarbons. Thus, if we represent the per centage of hydrocarbons absorbed by sulphuric acid by A., the volume of carbonic acid generated by 100 vols. of the original gas by B., the carbonic acid formed by the gas remaining after the absorption of hydrocarbons from 100 vols. of original gas by C., and the volume of carbonic acid generated by the combustion of the hydrocarbons alone by x, we have the following equation—

$$x = c - b;$$

and therefore the amount of carbonic acid generated by 1 vol. of the hydrocarbons is represented by $\frac{c-b}{A}$, but as 1 vol. of carbon vapour generates 1 vol. of carbonic acid, this fraction also expresses the quantity of carbon vapour in 1 vol. of the luminiferous constituents. For the purpose of comparison, however, I prefer to represent the value of these hydrocarbons in their equivalent volume of olefiant gas, 1 vol. of which contains 2 vols. of carbon vapour; to effect this the last expression need only be changed to $\frac{c-b}{2A}$. Thus if there exist in a specimen of gas 10 per cent. of hydrocarbons, one volume of which contains 3 vols. of carbon vapour, the quantity of olefiant gas to which this 10 per cent. is equivalent will be 15.

The necessity for this valuation will be evident when I state that one volume of the hydrocarbons absorbable by chlorine, or fuming sulphuric acid, (for both these materials condense precisely the same ingredients if light be perfectly excluded during the action of the chlorine,) contains quantities of carbon vapour, varying from 2·54 volumes to 4·36 volumes, from which it is evident that two gases undergoing the same amount of condensation from the chlorine and sulphuric acid tests, might still differ in illuminating power to the extent of more than 71 per cent.

In his very carefully performed experiments upon Boghead and Lesmahago cannels, Dr. Fyfe found that practically their illuminating power was nearly equal, although the quantity of hydrocarbons contained in the Boghead gas, as shewn by the chlorine test, was 27 per cent., whilst the Lesmahago gas contained only 17·6 per cent.; and Dr. Fyfe suggested that this equality of light might be owing to our not being yet acquainted with the method of burning rich gases to advantage; but on determining the quantity of carbon contained in equal volumes of the Boghead and Lesmahago hydrocarbons, I find that 17·6 volumes of the Lesmahago hydrocarbon contain nearly as much carbon as 27 volumes of the Boghead hydrocarbon, which satisfactorily demonstrates this to be the cause of the equality in illuminating power.

The following are the results of the experiments upon the process applied to resin:—

I.—PRACTICAL RESULTS.

		Materials Consumed.					Products Obtained.		
	Average evolution of Gas per hour.	Resin.	Coal.	Charcoal	Lime.	Watr.	Resin Oil.	Gas.	Gas per Cwt. of Resin.
	Cub. feet	Cwt. qr. lb	Cwt. qr.	lb	lb	lb	Galls.	Cb.ft.	
1st Experiment	930	2 1 17½	1 2	10	20	73	10.7	3340	1388
2nd "	1000	2 1 18	1 2	12	20	77	7.8	3800	1576
3rd "	......	2 0 17	1 2	12	28	85	4.5	4157	1932
4th "	......	2 0 7	1 2	10	28	62½	8.75	3090	1520

Average production of Gas per ton of Resin............32,080 cubic feet.

Average production of Resin Oil per ton of Resin............70.3 gallons.

Illuminating power of average Gas before purification, as ascertained by shadow test, .75 cubic feet per hour = light of one short six candle.

ANALYTICAL RESULTS.

COMPOSITION OF GAS BEFORE PURIFICATION.

	Actual Amount in Cubic Feet.					Per Centage Amount.				
	1st Exp.	2nd Exp.	3rd Exp.	4th Exp.		1st Exp.	2nd Exp.	3rd Exp.	4th Exp.	Average.
Hydrocarbons	258.7	269.0	305.7			7.75	7.08	7.41	8.22	7.62
Light carbd. hydrgn.	587.5	1527.7	895.9			17.58	40.20	21.71	31.09	27.64
Hydrogen	1315.3	1274.8	1976 2			39.38	33.54	47.90	42.06	40.72
Carbonic oxide	967.9	319.2	753.3			28.98	8 40	18.26	15.04	17.67
Carbonic acid	210.6	409.5	194.9			6.31	10.78	4.72	3.59	6.35
	3340.0	3800.2	4126.0			100.00	100.00	100.00	100.00	100.00

Amount of Carbon Vapour contained in 1 volume of Hydrocarbons=2.8 volumes.

COMPOSITION OF GAS AFTER PURIFICATION.

	1st Exp.	2nd Exp.	3rd Exp.	4th Exp.	Average.
Hydrocarbous	8.27	7.94	7.78	8.53	8.13
Light carburetted hydrogen..	18.76	45.06	22.79	32.25	29.71
Hydrogen	42.03	37.59	50.27	43.62	43.38
Carbonic oxide..................	30.93	9.41	19.16	15.60	18.78
	100.00	100.00	100.00	100.00	100.00

Specific gravity of average Gas before purification=.65886.
" " " after " =.59133.

VALUE OF HYDROCARBONS EXPRESSED IN THEIR EQUIVALENT VOLUME OF OLEFIANT GAS.

	Value of Actual Amount.	Value of Percentage Amount in Purified Gas.
1st Experiment	362·2 Cubic feet.	11·58 Cubic feet.
2nd Experiment	376·6 " "	11·12 " "
3rd Experiment	428·0 " "	10·89 " "
4th Experiment		11·94 " "

The foregoing analytical results furnish us with a satisfactory explanation of the processes which go on both in the water and resin gas retorts. In the water retorts two distinct decompositions take place, viz., first, the decomposition of steam by charcoal, with the production of equal volumes of hydrogen and carbonic oxide gases; and second, the decomposition of steam by charcoal, with the formation of two volumes of hydrogen and one volume of carbonic acid.

The mixture of hydrogen, carbonic oxide, and carbonic acid along with a large excess of steam, then passes into the resin retort, where, mixing with the decomposing resin vapour, it twice traverses the whole length of the red hot vessel. There is no doubt that the greater portion of water gas is produced by the decomposition of this excess of steam in the resin retort, since the weight of charcoal required for the formation of the volume of water gas generated in each of the above experiments, is more than twice as great as that which disappeared from the water retort. This circumstance elucidates the advantages arising from the passage of this gas, mixed with steam, through the resin retort; the fuligenous matter, which would otherwise accumulate and block up this retort and its pipe, as is well known to be the case when resin alone is used, is converted into permanent combustible gas; this, although possessing no illuminating power, yields valuable service in rapidly sweeping out of the red-hot retort the permanent illuminating gases produced by the decomposition of the resin, and in saturating itself with the various volatile hydrocarbons, upon which so much of the illuminating power of all gas depends, and which would otherwise, to a great extent, be left behind with the tar and water in the condensers. It is well known how rapidly olefiant gas and all rich hydrocarbons are decomposed into charcoal and gases, possessing little or no illuminating power when in contact with the walls of a red-hot retort, and therefore the value of the water gas in thus rapidly removing them from this destructive influence, and retaining them in a permanently gaseous form, can scarcely be over-rated; indeed, this principle has not been entirely neglected in the manufacture of coal gas by the old process, several companies having attached exhausters to their retorts, which, however, perform their work very imperfectly, compared with the water gas.

The generation of water gas free from carbonic acid, although of no consequence in the process applied to coals and cannels, is a problem of great importance in its application to resin. The relative quantity of this gas produced varies so considerably, (from 10·78 to 4·72 per cent.,) owing no doubt to the degree of heat at which the decomposition takes place, and also probably to the rapidity with which the water is admitted into the retorts, that it is not impossible, by varying the condition, to get rid of it altogether. Its quantity appears to decrease as the temperature increases, but I have hitherto been unable entirely to prevent its formation. It is therefore requisite to have an efficient means for removing it from the gaseous mixture before it arrives at the holder, since this gas is not only entirely useless, being perfectly incombustible, but has a decidedly injurious influence on the combustion of the gas, by cooling the flame, and thus greatly diminishing the illuminating power. Lime, both in its wet and dry state, is quite inefficient for the removal of this carbonic acid, since the carbonate of lime first formed prevents further contact between the gas and the purifying agent. I therefore recommend caustic soda, produced by mixing lime with a solution of common soda, as a most efficient and inexpensive purifying agent when applied in the following manner:—Let 1 cwt. of soda be dissolved in not less than 120 gallons of water, (and proportionately for smaller quantities;) add to this 70 or 80 lbs. of quick lime; mix the whole well together and transfer it to the purifier, where it should be occasionally well agitated; after about 8000 cubic feet of gas have passed through, the mixture should be run off and allowed to settle in a suitable tank, from which the clear liquor floating above the sediment of carbonate of lime must be pumped up into the supply tank for the purifier, and, being again mixed with the same quantity of lime, used as before. Thus little or no loss of soda occurs, this base being simply used as a carrier of the carbonic acid from the gas to the lime. The sediment of carbonate of lime may be thrown away between each operation. The cost of purification by this method would not exceed ¾d. per 1000 cubic feet.

The 4th experiment was made with the purifier charged in the manner described, except that only 75 lbs. of soda were employed. The result of this experiment shows, that whilst the whole of the carbonic acid can be readily removed by this method, if the caustic soda be employed in sufficient quantity, and the gas brought in contact with a large surface of it, the quality of the gas is not in the least deteriorated in its passage through the liquid, as is proved by the increased per centage of olefiant gas.

A distinction must be made between unpurified coal gas and unpurified resin gas. The former contains many deleterious ingredients, which entirely prevent its use; the latter does not contain any noxious principle, but simply has its illuminating power diminished by the presence of carbonic acid. Its purity of composition and freedom from all substances which can, during combustion, produce compounds injurious to furniture, drapery goods, &c., gives the resin gas great advantages over coal gas, which always contains more or less bisulphuret of carbon,—which has hitherto defied all attempts to remove it or diminish its quantity by any process of purification—and which, during combustion, generates sulphurous acid, the compound to which all the mischief produced by coal is probably owing. The odour of the hydrocarbon gas, while it is sufficiently strong to give warning of any escape, is far less nauseous than that of the coal gas, and might even by some persons be deemed pleasant; whilst the process of manufacture is so simple, that any person of moderate intellect can at once conduct it.

WHITE'S PROCESS APPLIED TO COALS AND CANNELS.

The following experiments were conducted at the same works, and with the same apparatus as those on the process applied to resin; but in order to obtain a fair comparison of the results yielded by the various coals when distilled alone, as in the usual process of gas making, with those obtained from the same coals when treated with water gas, according to the new process, each coal was distilled first by itself, and then with the addition of water-gas, equal weights being used for each experiment; but as smaller quantities of gas were produced in these experiments than in the previous ones on resin, it was necessary to avoid any error which might arise from intermixture of the gases filling the small refrigerator, purifiers, &c., between the retorts and the holder, previous to the commencement of each experiment, and therefore the capacity of these vessels was determined, and a quantity of gas considerably greater than requisite to fill them, and made under the same circumstances as that in the succeeding experiment, was passed through them before each trial commenced. This plan of clearing out the vessels and pipes was found to answer perfectly on testing it by passing alternately similar quantities of Wigan cannel gas and water-gas through them, and the observation of the number of feet indicated by the meter before the flame of a test burner, coming from the ingress pipe near the holder, fully assumed the illuminating power of the gas which was being produced.

This precaution being adopted, each experiment was commenced by charging one of the retorts, thoroughly cleaned out, with 1 cwt. of coal or cannel, which was distributed nearly equally between the upper and lower divisions; the lid being then replaced as quickly as possible, the distillation was continued, either with or without the addition of water gas, until all volatile matters were expelled from the coal retort. The water gas was produced, as usual, by allowing a thin stream of water to fall upon charcoal heated to full redness in a separate retort; this gas, along with the excess of steam, then passed into the lower division of the coal retort, sweeping in its course the gases forming in both the lower and upper divisions rapidly into the hydraulic main, and producing, in its passage, an additional quantity of water gas by the action of the steam upon the coal tar. The production of the water gas was so regulated as to be most rapid at the commencement of the experiment, and then gradually to decline to its close.

For the purification of the gases nothing more was used than two small purifiers, the one containing wet and the other dry lime; but on the large scale, arrangements ought to be made for removing ammonia as well as sulphuretted hydrogen. There is, however, no constituent contained in the gases made by the new process applied to coals, which requires means of purification different from those commonly used in all gas works.

The samples of gases employed for testing the illuminating power and for analysis, were collected in the following manner:—The main conveying the gas from the purifiers to the holder was tapped at a point just before it entered the meter, and a tube attached leading to a graduated gas-holder capable of containing 80 cubic feet. The flow of gas into this holder was so regulated by a stop-cock as to allow the admission of a certain per centage throughout the entire working; for instance, if a 10 per cent. sample was being taken, 10 feet entered this holder during the time 90 feet passed through the meter. The per centages varied from 3 to 10 in the different experiments, but they were always made as large as the size of the holder rendered practicable. The volume of gas thus extracted was noted, and added to the quantity indicated by the meter. This method is much more convenient and accurate than when a large holder is employed and the total quantity of gas operated upon, since a large holder, even when depressed to the greatest extent, must always contain a considerable quantity of gas from the previous operation, and thus the experiment is vitiated; whilst with a smaller vessel, this residue can always be got rid of by allowing a few cubic feet of the gas at the time generating, to blow through it simultaneously with the collection of the first portion of the sample.

A rather low heat was employed in all the experiments, as it was found to be the best as well for the coals alone as with water gas; and the results obtained in the trials of the coals without water gas, will rarely be found below those of other experimenters.

The temperature of the gases on reaching the meter was found to be no higher than that of the external atmosphere. The greatest care was taken to secure accuracy in the results and perfect fairness in the comparison between the coals distilled alone and with water gas. All the weighings were made before me, and every experiment from beginning to end was made under my own personal inspection.

The illuminating power was tested by Bunsen's Photometer,—a large number of the experiments being made with an improved form of the instrument, invented by Messrs. Church and Mann, of the City Gas Works, London. In some instances, the shadow test was also tried. The size of burner and pressure of gas were in most cases noted, and in every instance the determination of the illuminating power was made when the gas was burning to the greatest advantage, that is, without a flickering flame or a tendency to smoke. These experiments are, however, even with the greatest care, subject to certain errors, caused principally by the irregular burning of the spermaceti candle, rendering them only approximative. The liability to these errors has, it is true, been much reduced by the ingenious plan of substituting a jet of gas for the candle, as proposed by Mr. King and Mr. Wright; but yet the impossibility of accurately ascertaining the consumption of the candle, at the moment when the gas-jet is made equal to it, renders the experiments still liable to small inaccuracies. The following results are all corrected to those which would have been obtained by using a sperm candle burning 120 grs. per hour; and one of these candles burning 10 hours, is taken as the standard with which to compare the total quantity of light yielded by a given volume of gas. Thus, when it is stated that the total quantity of gas produced from 1 cwt. of coal, when burnt at the rate of 5 feet per hour, is equal to 546 candles, it is intended that the light afforded by the gas is equal to that yielded by 546 sperm candles, each burning 10 hours, and at the rate of 120 grs. per hour.

The following are the results of the experiments:—

WIGAN CANNEL, (INCE HALL.)

I.—WITHOUT WATER GAS.

Cannel used	1 cwt.
Gas produced	545 cubic feet.
Coke left	74 lbs.
Time occupied	3 h. 20 m.

ILLUMINATING POWER OF GAS.

Shadow Test.	2 cubic feet per hour.	3 cubic feet per hour.	4 cubic feet per hour.	5 cubic feet per hour.
$\frac{5}{10}$ cubic feet per hour = 1 candle.	Fish-tail No. 1. Press. .2 in. = 8.77 candles.	Fish-tail No. 1. Press. .4 in. = 13.9 candles.	Fish-tail No. 2. Press. .6 in. = 18.0 candles.	Fish-tail No. 4. Press. .5 in. = 22.1 candles.

Total gas produced when burnt at 5 feet per hour, yields light = 240·8 sperm candles.

PER CENTAGE COMPOSITION OF DRY GAS.

Hydrocarbons and olefiant gas, equivalent to 15·13 per cent. of olefiant gas		10·81
Light carburetted hydrogen		41·99
Hydrogen		35·94
Carbonic oxide		10·07
Carbonic acid		1·19
Nitrogen	traces	——
Oxygen	traces	
		100·00

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydrocarbons and olefiant gas	58·05=31·27 olefiant gas.
Light carburetted hydrogen	225·48
Hydrogen	193·00
Carbonic oxide	54·07
Carbonic acid	6·39
Watery vapour*	8·01
	545·00

Amount of carbonic gas generated by 1 volume of hydrocarbons, &c., condensed by fuming sulphuric acid, = 2·8 volumes.

II.—WITH WATER GAS.

Cannel used	112 lbs.
Gas produced	806 cubic feet.
Coke left	68 lbs.
Time occupied	3 h. 20 m.

* It was found quite impossible to determine the quantity of watery vapour contained in each gas as it passed through the meter, since both the temperature of the gas and the degree of saturation were subject to variations during each experiment ; a mean amount of 1·47 per cent. has therefore been assumed as the watery vapour present in each case. Although this number is not absolutely accurate, it is more than sufficiently so for all practical purposes.

ILLUMINATING POWER OF GAS.

Shadow Test.	2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.
.575 cubic feet per hour = 1 candle.	Fish-tail No. 2. Press. .7 in. = 8.6 candles.	Fish-tail No. 2. Press. .5 in. = 13.7 candles.	Fish-tail No. 2. Press. .6 in. = 15.8 candles.	Fish-tail No. 4. Press. .5 in. = 20 candles.

Total gas produced when burnt at the rate of 5 feet per hour, yields light = 322·4 sperm. candles.

PER CENTAGE COMPOSITION OF DRY GAS.

Hydrocarbons and olefiant gas equivalent to 13·72 per cent. olefiant gas	10·55
Light carburetted hydrogen	27·20
Hydrogen	47·39
Carbonic oxide	14·86
Carbonic acid	0·00
Oxygen and Nitrogen, (traces)	——
	100·00

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydrocarbons and olefiant gas	83·77 = 108·9 olefiant gas.
Light carburetted hydrogen	215·97
Hydrogen	376·28
Carbonic oxide	117·99
Watery vapour	11·99
	806·00

Amount of carbonic acid generated by 1 volume of condensible hydrocarbons = 2·60 volumes.

	Per cwt.	Per ton.	Per cent.
Hence gain in illuminating power by the employment of water gas	81·6 candles.	1632 candles.	33·9 candles.
And gain in olefiant gas	=27·63 cub. ft.	552·6 cub. ft.	34 cub. ft.
Gain in quantity of gas	=261 " "	5220 " "	47·9 " "

BOGHEAD CANNEL.

I.—WITHOUT WATER GAS.

Cannel used	112 lbs.
Gas produced..	662 cubic feet.
Coke left..	36 lbs.
Time occupied	2 h. 55 m.

ILLUMINATING POWER OF GAS.

Shadow Test.	1 foot per hour.	2 feet per hour.	3 feet per hour.	5 feet per hour.
.325 cubic feet per hour = 1 candle.	Fish-tail burner.* Press. .9 in. = 6.48 candles.	Fish-tail. Press. 1.2 in. = 14.4 candles.	Fish-tail. Press. .6 in. = 25.7 candles.	Winfield's Button Burner. = 52.6 candles.

Total gas produced when burnt at the rate of 3 feet per hour, yields light = 567 sperm candles.

PER CENTAGE COMPOSITION OF DRY GAS.

Hydrocarbons and olefiant gas equivalent to 31·11 per cent. olefiant gas..	24·50
Light carburetted hydrogen..........................	58·38
Hydrogen	10·54
Carbonic oxide	6·58
Carbonic acid..	0·00
	100·00

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydrocarbons and olefiant gas	159·7=202·8 olefiant gas.
Light carburetted hydrogen	380·8
Hydrogen	68·8
Carbonic oxide	42·9
Aqueous vapour	9.8
	662·0

* The fish-tail burners used in these experiments were very small, and made expressly for this exceedingly rich gas.

Amount of carbonic acid generated by 1 volume of hydrocarbons, condensed by fuming sulphuric acid=2·54 volumes.

II.—WITH WATER GAS.

Cannel used	112 lbs.
Gas produced	1908 cubic feet.
Coke left	37½ lbs.
Time occupied	3 hours.

ILLUMINATING POWER OF GAS.

Shadow Test.	2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.	8 feet per hour.
.425 cubic feet per hour = 1 candle.	Fish-tail No. 1. Press. .3 in. = 11.2 candles.	Fish-tail No. 2. Press. = 16.8 candles.	Fish-tail No. 4. Press. .4 in. = 20.0 candles.	Fish-tail No. 4. Press. .6 in. = 29.7 candles.	Winfield's Burner. = 50.6 candles.

Total gas produced when burnt at the rate of 3 feet per hour, yields light = 1068·4.

PER CENTAGE COMPOSITION OF DRY GAS.

Hydrocarbons and olefiant gas equivalent to 19·84 per cent. olefiant gas	14·12
Light carburetted hydrogen	22·25
Hydrogen	45·51
Carbonic oxide	14·34
Carbonic acid	3·78
	100·00

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydrocarbons and olefiant gas	265·5=373 olefiant gas.
Light carburetted hydrogen	418·2
Hydrogen	855·5
Carbonic oxide	269·6
Carbonic acid	71·0
Aqueous vapour	28·2
	1908·0

Amount of carbonic acid generated by 1 volume of condensible hydrocarbons = 281 volumes.

	Per cwt.	Per ton.	Per cent.
Hence gain in illuminating power by the employment of water gas	501.4 candles.	10.028 candles.	88.4 candles.
And gain in olefiant gas	170.2 cub. ft.	3404 cub. ft.	83.9 cub. ft.
Gain in quantity of gas	1246 " "	24920 " "	188.2 " "

NOTE.—The following is the per centage composition of this extraordinary cannel according to the mean of two analyses made with great care by my assistant Mr. Russell:—

Carbon	65.34
Hydrogen	9.12
Oxygen	5.46
Nitrogen............	.71
Sulphur	.15
Water............	.54
Ash............	18.68
	100.00

In this experiment it was found impossible to generate more than one half of the requisite quantity of water gas from the water retort connected with that in which the cannel was distilled, and consequently another water retort had to be employed; but this, instead of pouring its gas into the coal retort, delivered it directly into the hydraulic main; thus reducing the advantageous operation of the water gas in rapidly sweeping out the illuminating gases from the coal retort, and, in addition, preventing the removal of a considerable amount of carbonic acid, which materially diminished the illuminating power, as indicated by the photometer.

I have since had the opportunity of repeating the experiment with a new apparatus, consisting of one coal and two water retorts, both of the latter delivering their gas into the lower division of the former: the other conditions of the experiment were the same as before.

SECOND EXPERIMENT.

Cannel used	112 lbs.
Gas produced	2586 cubic feet.
Time occupied	3 h. 15 m.

ILLUMINATING POWER OF GAS.

2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.	5 feet per hour.
Fish-tail No. 1. 6 candles.	Fish-tail No. 1. 10.1 candles.	Fish-tail No. 4. 15.1 candles.	Fish-tail No. 4. 17.9 candles.	Leslie's Burner 20.0 candles.

Total gas produced when burnt at the rate of 5 feet per hour, yields light = 1034.4 sperm candles.

	Per cwt.	Per ton.	Per cent.
Hence gain in illuminating power by application of water gas process	467.4 candles.	934.8 candles.	82.4
Gain in quantity of gas	1924 cub. ft.	38,480 cub. ft.	290.6 cub. ft.

No analyses were made in connection with this experiment, but it was carefully ascertained that the gas did not contain more than a mere trace of carbonic acid.

The experiment thus demonstrates the fact that the whole of the carbonic acid is removed from the water gas during its passage through the coal retort, even when Boghead cannel is employed, and also that the enormous quantity of 51,720 cubic feet of gas, possessing a high illuminating power, is capable of being produced from 1 ton of the Boghead cannel; but it does not show, as might have been expected, that the additional quantity of water gas passed through the coal retort has had the effect of preserving more of the illuminating hydrocarbons than in the previous experiment; on the contrary, a slight diminution of total illuminating power is seen on comparing the results of the two experiments. But this diminution is accounted for, when we consider that the first experiment was made in summer, whilst the last was performed during the last frost and with the holder covered with snow; the gas therefore passed through a species of ice-test, and suffered a small diminution of illuminating power, the extent of which we shall speak of presently.

LESMAHAGO CANNEL.

I.—WITHOUT WATER GAS.

Cannel used	112 lbs.
Gas produced	531 cubic feet.
Coke left	54¼ lbs.
Time occupied	3 h. 20 m.

ILLUMINATING POWER OF GAS.

Shadow Test.	2 feet per hour.	3 feet per hour.	4 feet per hour.	4½ feet per hour.
.35 cubic feet per hour = 1 candle.	Fish-tail No. 1, Press. .6 in. = 12.1 candles.	Fish-tail No. 1. Press. .6 in. = 23.2 candles.	Fish-tail No, 3. Press. .5 in. = 28.7 candles.	Fish-tail No. 3. Press. .6 in. = 36 candles.

Total quantity of gas when burnt at the rate of 4 feet per hour, yields light = 381 sperm candles.

PER CENTAGE COMPOSITION OF DRY GAS.

Hydrocarbons and olefiant gas equivalent to 28.30 per cent. olefiant gas	16.31
Light carburetted hydrogen	42.01
Hydrogen	26.84
Carbonic oxide	14.18
Carbonic acid	.66
Oxygen and nitrogen (traces)	—
	100.00

ACTUAL CONSTITUENTS.

	Cubic feet.	
Hydrocarbons and olefiant gas	85.3	= 148 olefiant gas.
Light carburetted hydrogen	219.8	
Hydrogen	140.5	
Carbonic oxide	74.2	
Carbonic acid	3.4	
Aqueous vapour	7.8	
	531.0	

Amount of carbonic acid produced by 1 volume of condensible hydrocarbons = 3.47 volumes.

II.—WITH WATER GAS.

Cannel used	112 lbs.
Gas produced	1459 cubic feet.
Coke left	49 lbs.
Time occupied	3 h. 18 m.

ILLUMINATING POWER OF GAS.

Shadow Test.	2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.
.5 cubic feet per hour = 1 candle.	Fish-tail No. 2. Press. .5 in. = 9.3 candles.	Fish-tail No. 2. Press. .6 in. = 13.2 candles.	Fish-tail No. 2. Press. .6 in. = 19.1 candles.	Fish-tail No. 4. Press. .5 in. = 28.7 candles.

Total quantity of gas when burnt at the rate of 4 feet per hour, yields light = 696.7 sperm candles.

PER CENTAGE COMPOSITION OF DRY GAS.

Hydrocarbons and olefiant gas equivalent to 19.05 per cent. olefiant gas	10.89
Light carburetted hydrogen	18.94
Hydrogen	55.09
Carbonic oxide	15.02
Carbonic acid	.06
	100.00

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydrocarbons and olefiant gas	156.5 = 273.9 olefiant gas
Light carburetted hydrogen	272.3
Hydrogen	791.9
Carbonic oxide	215.9
Carbonic acid	.9
Aqueous vapour	21.5
	1459.0

Amount of carbonic acid generated by 1 volume of condensible hydrocarbons = 3.50 volumes.

	Per cwt.	Per ton.	Per cent.
Gain in illuminating power by application of water gas =	315.7 candles.	6314 candles.	82.8
Gain in quantity of olefiant gas ...	125.9 cub. ft.	2518 cub. ft.	85.1
Gain in total quantity of gas produced	928 "	18,560 "	174.8

METHYL CANNEL.

I.—WITHOUT WATER GAS.

Cannel used	112 lbs.
Gas produced	478 cubic feet.
Coke left	51 lbs.
Time occupied	3 hours.

ILLUMINATING POWER OF GAS.

1 foot per hour.	2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.
Fish-tail No. 1 = 3.7 candles.	Fish-tail No. 1. = 10.1 candles.	Fish-tail No. 1. = 17.4 candles,	Fish-tail No. 2. = 21.5 candles.	Fish-tail No. 3. = 27.8 candles.

Illuminating power of total gas burnt at the rate of 5 feet per hour = 265.8 candles.

PER CENTAGE COMPOSTION OF GAS.

Hydrocarbons and olefiant gas equivalent to 13.53 per cent olefiant gas	14.48
Light carburetted hydrogen	38.75
Hydrogen	33.32
Carbonic oxide	13.40
Carbonic acid	.05
Nitrogen and Oxygen, (traces)	——
	100.00

Amount of carbonic acid generated by 1 volume of condensible hydrocarbons = 2.56 volumes.

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydrocarbons and olefiant gas	68.2=87.3 olefiant gas.
Light carburetted hydrogen	182.5
Hydrogen	156.9
Carbonic oxide	63.1
Carbonic acid	.3
Aqueous vapour	7.0
	478.0

II.—WITH WATER GAS.

Cannel used	112 lbs.
Gas produced	1320 cubic feet.
Coke left	51 lbs.
Time	3 hours.

ILLUMINATING POWER OF GAS.

2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.
Fish-tail No. 1. = 7.2 candles.	Fish-tail No. 2. = 10.7 candles.	Fish-tail No. 2. = 15.3 candles.	Fish-tail No. 4. = 21 candles.

Illuminating power of total quantity of gas burnt at the rate of 5 feet per hour = 554.4 candles.

PER CENTAGE COMPOSITON OF GAS.

Hydrocarbons and olefiant gas equivalent to 14.05 per cent. olefiant gas	11.06
Light carburetted hydrogen	22.89
Hydrogen	45.58
Carbonic oxide	20.44
Carbonic acid	.03
Nitrogen and Oxygen, (traces)	——
	100.00

Amount of carbonic acid generated by 1 volume of condensible hydrocarbons=2.54 volumes.

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydrocarbons and olefiant gas	143.8=182.6 olefiant gas.
Light carburetted hydrogen	297.8
Hydrogen	592.7
Carbonic oxide	265.8
Carbonic acid	.4
Aqueous vapour	19.5
	1320.0

	Per cwt.	Per ton.	Per cent.
Gain in illuminating power by application of water gas =	288.6 candles.	5772 candles.	108.6
Gain in quantity of olefiant gas	95.3 cub. ft.	1906 cub. ft.	109.2
Gain in quantity of gas	842 " "	16,840 " "	176.2

NEWCASTLE CANNEL, (RAMSAY'S.)

I.—WITHOUT WATER GAS.

Cannel used	112 lbs.
Gas produced	515 cubic feet.
Coke left	74½ lbs.
Time occupied	3 h. 25 m.

ILLUMINATING POWER OF GAS.

Shadow Test.	2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.
.575 cubic feet per hour = 1 candle,	Fish-tail No. 1. Press. .4 in. = 8.4 candles.	Fish-tail No. 1. Press. .5 in. = 11.9 candles.	Fish-tail No. 1. Press. .8 in. = 20.0 candles.	Fish-tail No. 2. Press. ,8 in. = 24.5 candles.

Illuminating power of total gas when burnt at the rate of 5 feet per hour = *252.3* sperm candles.

PER CENTAGE COMPOSITION OF GAS.

Hydrocarbons and olefiant gas equivalent to 16.94 per cent olefiant gas	9.68
Light carburetted hydrogen	41.38
Hydrogen	33.30
Carbonic oxide	15.64
Carbonic acid	0.00
	100.00

Amount of carbonic acid generated by 1 volume of condensible hydrocarbons = *3.50* volumes.

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydrocarbons and olefiant gas	49·1=85·9 olefiant gas.
Light carburetted hydrogen	210·0
Hydrogen	168·9
Carbonic oxide	79·4
Aqueous vapour	7.6
	515.0

II.—WITH WATER GAS.

Cannel used	112 lbs.
Gas produced	751 cubic feet.
Coke left	74 lbs.
Time occupied	3 h. 25 m.

ILLUMINATING POWER OF GAS.

Shadow Test.	2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.	6 feet per hour.
.725 cubic feet per hour = 1 candle.	Fish-tail No. 2. Press. .4 in. = 5.8 candles.	Fish-tail No. 2. Press. .6 in. = 10.3 candles.	Fish-tail No. 2. Press. .6 in. = 14.1 candles.	Fish-tail No. 4. Press. .8 in. = 18.8 candles.	Fish-tail No. 4. Press. .7 in. 23.2 candles.

Illuminating power of total gas when burnt at the rate of 5 feet per hour = 282.3 sperm candles.

PER CENTAGE COMPOSITION OF GAS.

Hydrocarbons and olefiant gas equivalent to 13.15 per cent. olefiant gas	9.04
Light carburetted hydrogen	26.84
Hydrogen	44.26
Carbonic oxide	19.39
Carbonic acid	.47
	100.00

Amount of carbonic acid generated by 1 volume of condensible hydrocarbons = 2.91 volumes.

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydrocarbons and olefiant gas	66.9 = 97.3 olefiant gas.
Light carburetted hydrogen	198.6
Hydrogen	327.5
Carbonic oxide	143.5
Carbonic acid	3.4
Aqueous vapour	11.1
	751.0

Hence—

	Per cwt.	Per ton.	Per cent.
Gain in illuminating power by the employment of water gas =	30 candles.	600 candles.	11.2
Gain in quantity of olefiant gas	11.4 cub. ft.	228 cub. ft.	13.3
Gain in total quantity of gas	236 " "	4720 " "	45.8

The results yielded by this cannel are very different from those obtained with the same material at the Western Gas Works, London. Mr. Wright, the eminent engineer to the Western Gas Company, has lately made a series of experiments, conducted with great care and accuracy, upon the gas there produced, and states that a flame consuming 3 feet per hour produced light equal to from 16.6 to 20 candles; and this statement is perfectly corroborated by my own analysis of a specimen of the Western Company's gas collected June 15th, 1851, and given below. As I have not had an opportunity of repeating the practical examination, I can only reconcile these discordant results by supposing either that the specimen of Newcastle cannel sent me for investigation was of inferior quality, or that some unknown disturbing cause interfered with my experiments upon it. I should anticipate that at least 29,000 cubic feet of gas per ton, with an illuminating power equal to 20 candles for a consumption of 5 feet per hour, could be obtained from this cannel by the application of water gas, if of the same quality as that used at the Western Gas Company's works, Paddington.

WIGAN CANNEL, (BALCARRES.)

I.—WITHOUT WATER GAS.

Cannel used	112 lbs.
Gas produced	522 cubic feet.
Coke left	68¼ lbs.
Time occupied	3 h. 25 m.

ILLUMINATING POWER OF GAS.

Shadow Test.	2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.
.675 cubic feet per hour = 1 candle.	Fish-tail No. 2. Press. .4 in. = 6.0 candles.	Fish-tail No. 2. Press. .5 in. = 10.9 candles.	Fish-tail No. 2. Press. .6 in. = 14.7 candles.	Fish-tail No. 4. Press. .6 in. = 19.9 candles.

Illuminating power of total gas when burnt at the rate of 5 feet per hour = 207.8 candles.

No analyses of this and the following specimen of gas were made.

II.—WITH WATER GAS.

Cannel used	112 lbs.
Gas produced	775 cubic feet.
Coke	67¾ lbs.
Time occupied	3 h. 15 m.

ILLUMINATING POWER OF GAS.

Shadow Test.	2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.
.7 cubic feet per hour = 1 candle.	Fish-tail No. 1. Press. .4 in. = 5.6 candles.	Fish-tail No. 3, Press. .4 in. = 9,5 candles.	Fish-tail No. 3. Press. ,5 in. = 14.1 candles.	Fish-tail No. 4. Press, .6 in. = 19.1 candles.

Illuminating power of total gas when burnt at the rate of 5 feet per hour = 296 candles.

Hence—

	Per cwt.	Per ton.	Per cent.
Gain in illuminating power by the employment of water gas ... =	88.2 candles.	1764 candles.	42.4
Gain in total quantity of gas ... =	253 cubic feet.	5060 cubic ft.	48.5

NEWCASTLE COAL, (PELTON.)

I have not ascertained the results which this coal yields with water gas, owing to an experiment which I made being rendered useless by the occurrence of a leakage in the apparatus, the sample of coal at my disposal being so nearly exhausted as not to leave a sufficient quantity for a repetition of the trial. The following examination of the gas produced from the coal distilled without water gas, may not, however, prove entirely uninteresting.

NEWCASTLE COAL, (PELTON.)

WITHOUT WATER GAS.

Coal used	112 lbs.
Gas produced	504 cubic feet.
Coke left	70 lbs.

ILLUMINATING POWER OF GAS.

2 feet per hour.	3 feet per hour.	4 feet per hour.	5 feet per hour.	6 feet per hour.
Fish-tail No. 1. Press. = .6 in. = 4.6 candles.	Fish-tail No. 2. Press. .6 in. = 8.8 candles.	Fish-tail No. 3. Press. .4 in. = 12.15 candles.	Fish-tail No. 4. Press. .4 in. = 14.9 candles.	Fish-tail No. 4. Press. .6 in. = 17.0 candles.

Illuminating power of total gas when burnt at the rate of 5 feet per hour = 150.2 candles.

PER CENTAGE COMPOSITION OF GAS.

Hydro-carbons and olefiant gas equivalent to 7.16 per cent. olefiant gas	3.87
Light carburetted hydrogen	32.87
Hydrogen	50.05
Carbonic oxide	12.89
Carbonic acid	.32
Nitrogen and oxygen (traces)	—
	100.00

Amount of carbonic acid generated by 1 volume of condensible hydrocarbons = 3.70 volumes.

ACTUAL CONSTITUENTS.

	Cubic feet.
Hydro-carbons and olefiant gas	19.2=35.5 olefiant gas.
Light carburetted hydrogen	163.2
Hydrogen	248.5
Carbonic oxide	64.0
Carbonic acid	1.6
Aqueous vapour	7.5
	504.0

The foregoing experiments give us a much more complete insight into this process of gas making than did the previous ones on resin gas; and they also bring to light several circumstances highly favourable to it, which could scarcely have been predicted previous to the actual trials being made. The first and most important of these is the disappearance of the carbonic acid contained in the water gas during its passage through the coal retort. This disappearance is so complete that the resulting gaseous mixture actually contains a much smaller per centage than does the gas obtained by the distillation of the coal alone. It is true that the gases examined in the above experiments had streamed through small wet and dry lime purifiers; but I have shown that in the production of gas from resin, lime was almost useless for removing carbonic acid in these purifiers, and that, even when charged with caustic soda, they still left 3.59 per cent. in the gas. It is therefore certain, that the carbonic acid of the water gas is destroyed by some action taking place during its passage through the coal retort; thus obviating all trouble and expense of removing this gas by any purifying process whatever. There is little doubt that this removal of the carbonic acid depends upon its conversion into carbonic oxide gas by the carbonaceous matters in the coal retort; and of these the coke is probably the most active, since the volatile matters do not differ materially from those produced during the distillation of resin; and these, we have seen, fail to remove the acid gas.

Another favourable circumstance occurring in the process consists in the relatively small quantity of carbonic oxide that is produced; a large proportion of this gas would be equally objectionable with a high per centage of light carburetted hydrogen, so far as the quantity of carbonic acid formed during its subsequent combustion is concerned; a reference to the composition of the foregoing gases shows us, however, that in all cases the amount of carbonic acid generated is less than that formed by the combustion of an equal volume of the gas obtained from the same coals by the ordinary process of manufacture, and in some cases it is even less than that produced by a pure coal gas flame giving an equal light. The following table shows this comparison:—

Name of Gas.	Cubic feet of carbonic acid produced by combustion of 100 cubic feet of gas.	Cubic feet of carbonic acid produced per hour by a light equal to 20 candles.
Ince Hall cannel	83.5	3.76
Ditto with water gas	69.5	3.47
Methyl cannel	89.3	3.32
Ditto with water gas	71.5	3.40
Ramsay's Newcastle cannel	90.9	3.64
Ditto with water gas	72.8	3.86
Lesmahago cannel	113.9	2.95
Ditto with water gas	72.1	3.02
Boghead cannel	127.2	2.96
Ditto with water gas	76.3	3.05

The favourable position which the gases made by the new process occupy in the above comparison, could not have been attained if the whole or even a very large portion of the water gas had been generated in the charcoal retort; for when water gas alone is so generated, it is found to consist of hydrogen and carbonic oxide, mixed with quantities of carbonic acid, varying from 0 to 15 per cent. according to the heat employed and other circumstances. When the per centage of the acid gas is 0, then the volumes of hydrogen and carbonic oxide are equal; and as no important quantity of carbonic acid was ultimately present in the gases produced in the foregoing experiments, the whole of that gas entering the coal retort must be converted into carbonic oxide, and therefore we may consider the water gas entering the coal retort as being composed of equal volumes of hydrogen and carbonic oxide. Now, if the increase in the total quantity of gas produced by the application of the new process to any given coal or cannel, were due only to the water gas formed in the charcoal retort, it is obvious that the gain in carbonic oxide ought to be equal to the gain in hydrogen; but a glance at the analytical results shows that this is far from being the case; thus with—

BOGHEAD CANNEL.

The gain in hydrogen ...... = 786.9 cubic feet.
And " carbonic oxide = 226.7 "

Hence, gain in hydrogen : gain in carbonic oxide = 3.5 : 1. With—

LESMAHAGO CANNEL.

The gain in hydrogen ...... = 651.2 cubic feet.
And " carbonic oxide = 141.6 "

Hence, gain in hydrogen : gain in carbonic oxide = 4.6 : 1. With—

INCE HALL CANNEL.

The gain in hydrogen ...... = 183 cubic feet.
And " carbonic oxide = 63.9 "

Hence, gain in hydrogen : gain in carbonic oxide = 2.9 : 1. With—

RAMSAY'S NEWCASTLE CANNEL.

The gain in hydrogen ...... = 158.7 cubic feet.
And " carbonic oxide = 64.2 "

Hence, gain in hydrogen : gain in carbonic oxide = 2.5 : 1. And with—

METHYL CANNEL.

The gain in hydrogen ...... = 435.6 cubic feet.
And " carbonic oxide = 202.6 "

Hence, gain in hydrogen : is to gain in carbonic oxide = 2.2 : 1.

It is therefore evident, that a large quantity of water gas must be generated by the action of steam upon the carbonaceous materials in the coal retort, and that this water gas contains a very much greater per centage of hydrogen than that produced in the charcoal retort. Although we are not yet sufficiently acquainted with the action of watery vapour upon organic substances at high temperature, to state positively the cause of this excess of hydrogen, yet there can be little doubt that it is derived from the action of steam upon the hydrocarbons of the tar; for as watery vapour in acting upon carbon transfers its oxygen to that element, forming carbonic oxide and an equal volume of hydrogen, so also when steam acts upon a compound of carbon and hydrogen, it produces carbonic oxide, but in doing so sets at liberty not only its own hydrogen but that of the carbohydrogen also; and thus the volumes of hydrogen and carbonic oxide remain no longer equal, but the volume of the former becomes double, treble, or even fourfold that of the latter. Thus the non-luminous gases contain a very large proportion of hydrogen, which, as we have already proved, is very much preferable to carbonic oxide and light carburetted hydrogen, on account of the relatively small extent to which a given volume vitiates the atmosphere and heats the apartments in which it is consumed.

It has been supposed that the gases generated by the new process have, to some extent, the nature of naphthalized gases, and that, therefore, when allowed to stand for some time in the holder, and especially when exposed to a freezing temperature, their illuminating power would be much deteriorated. It was of importance carefully to ascertain the value of this objection, and I therefore allowed a specimen of the Boghead hydrocarbon gas to stand over water in a holder for forty-eight hours, but at the expiration of that time, its illuminating power had not suffered the least deterioration. I then exposed various specimens of gas to the temperature of melting ice for several hours; the usual mode of doing this, by allowing the gas to stream through a serpentine pipe surrounded by ice, is nearly valueless, since the temperature of the gas does not become reduced to 32° unless the tube be inconveniently long and the stream very slow; and if any hydrocarbons are condensed, they have not time entirely to deposit, but a portion is carried forward in the vesicular condition, until on emerging from the refrigerator it is again gasified by the increasing temperature. To avoid these errors an apparatus* was employed in the following experiments, by means of which the volume of the gas saturated with watery vapour, and at the temperature of about 60°F., could be accurately ascertained, and the gas then transferred without loss into the refrigerator, where it was exposed to 32° for not less than one hour; it was then transferred into the measuring portion of the apparatus, the pressure upon the gas being constantly preserved equal to that of the external atmosphere; when the gas had again become perfectly saturated with watery vapour, its volume at 60°F. was again ascertained; the difference gave the loss of hydrocarbons in the refrigerator. I have not submitted all the gases to this test; but it has been applied to a sufficient number to show that those made by the new process, so far from losing more illuminating materials by exposure to cold, lose in all cases less than the corresponding gas made by the usual process from coal alone.

The following are the results of these experiments:—

NAME OF GAS.	Cubic feet of hydrocarbons condensed from 100 cubic feet of gas on exposure to a cold of 32° F.
Boghead	4.42 cubic feet.
" with water-gas	.24 "
Methyl	.33 "
" with water-gas	.07 "
Ince Hall	.37 "

* This apparatus will be fully described along with the one used for the analysis of the gases.

There is little doubt that all descriptions of coal gas experience some loss of illuminating principles on exposure to a cold of 32°, but the gases richest in hydrocarbons will lose generally the largest proportion; and hence the advantage of diluting such gases so as to afford more space for the vapours of these hydrocarbons, and thus prevent their condensation. This advantage is seen most strikingly in the behaviour of Boghead gas, with and without water gas, when exposed to the ice test. The difference in the case of Lesmahago would probably be still more striking, as, from the much greater density of its hydrocarbons, it might be expected to lose a large proportion when submitted to the ice test in its pure state.

For the purpose of comparison with the above experiments, I have analysed the gases supplied to consumers from the Manchester Corporation works, and by several of the London companies. The specimens were all collected by myself; that of the Manchester gas in June, and those of the London gases on the 15th of July, 1851. In some instances they were taken from the burner of the consumer, in others at the works. At the offices of two of the London companies I was kindly permitted to take the illuminating power of the gas by means of a Bunsen's photometer; the illuminating power of the other gases is deduced from the analytical results.

I have assumed that the sperm candles used in the experiments just alluded to were burning 130 grs. of sperm per hour, and have corrected the observations to the standard of 120 grs. per hour. For obvious reasons, I omit the names of the companies by whom the various gases were supplied.

The following are the numbers obtained:—

	Name of Coal.	Illuminating Power.		Per Centage Composition.							Value of hydro-carbons in eq. vol. of olefiant gas.
		By Photometer.	Calculated from Analysis.	Hydro-carbons.	Light carb. hydrogen.	Hydrogen.	Carbonic oxide.	Carbonic acid.	Nitrogen	Oxygen.	
Gas A......	Hulton Cannel ...	....	5 ft. per hr. = 14.3 can.	5.50	40.12	45.74	8.23	.41	trace.	....	9.96
Gas B......	Newcastle Coal...	5 ft. per hr. = 13 cand.	....	3.05	41.50	47.60	7.32	.53	"	....	6.97
Gas C......	Newcastle Coal...	5 ft. per hr. = 14.1 can.	....	3.56	35.28	51.24	7.40	.28	1.80	.44	7.21
Gas D......	Unknown	5 ft. per hr. =	5 ft. per hr. = 11.5 can.	3.67	40.66	41.15	8.02	.29	5.01	1.20	6.15
Gas E......	Newcastle Coal...	....	5 ft. per hr. = 14.4 can.	3.53	35.2	51.81	8.95	0.00	.38	.08	7.70
Gas F......	Newcastle Cannel	....	5 ft. per hr. = 34.4 can.	13.06	51.20	25.82	7.85	.13	1.51	.43	22.98

The per centage amount of olefiant gas contained in the Pelton gas and the gases marked B and C in the above table, all of them coal gases, would lead us to infer that their illuminating power is much lower than is really the case, for according to the experiments upon cannel gases, it appears that when a consumption of 5 feet per hour produces a light equal to 20 candles, the gas contains 13.72 per cent. of olefiant gas, or its equivalent in richer hydrocarbons; and, hence, we should expect that a gas containing only half this amount would, when burnt at the same rate, produce a light equal only to 10 candles, instead of 13, as is found to be the case. This excess of illuminating power in the case of *coal* gases over that indicated by analysis, is probably owing to the presence of luminiferous constituents not condensible either by fuming sulphuric acid, or by chlorine. The nature of these constituents, and the cause why they cannot be detected by our present methods of gas analysis, I have already pointed out, (Journal of Chemical Society, vol. iii. p. 42.) The following table exhibits this difference between the value of olefiant gas in coal gas, compared with that in cannel gas, and shows also, that in the case of the latter the illuminating power is always directly proportional to the amount of olefiant gas to which the per centage of condensible hydrocarbons is equivalent. The establishment of this rule with regard to gases having such different per centages of light carburetted hydrogen as the Boghead gas, with and without water gas, I hold to be conclusive evidence that light carburetted hydrogen has no higher illuminating power than hydrogen or carbonic oxide.

Value of 1 cubic foot of the olefiant gas, contained in the following gases, expressed in sperm candles, each burning 10 hours, at the rate of 120 grs. per hour.

CANNEL GASES.

Ince Hall cannel	2.95 candles.
Ditto with water gas	2.96 "
Boghead cannel	2.80 "
Ditto with water gas	2.83 "
Lesmahago cannel	2.58 "
Ditto with water gas	2.54 "
Ramsay's Newcastle cannel	2.88 "
Ditto with water gas	2.86 "
Methyl cannel	3.04 "
Ditto with water gas	3.03 "

COAL GASES.

Pelton coal	4.23 candles.
Gas B	3.73 "
Gas C	3.91 "

The conclusion resulting from the application of Mr. White's hydrocarbon process to coals and cannels may be thus summed up :—

1. It greatly increases the produce in gas from a given weight of coal or cannel, the increase being from 46 to 290 per cent. according to the nature of the material operated upon.

2. It greatly increases the total illuminating power afforded by a given weight of coal, the increase amounting to from 12 to 108 per cent., being greatest when coals affording highly illuminating gases are used.

3. It diminishes the quantity of tar formed, by converting a portion of it into gases possessing a considerable illuminating power.

4. It enables us profitably to reduce the illuminating power of the gases produced from such materials as Boghead and Lesmahago cannels, &c., so as to fit them for burning without smoke and loss of light.

5. It increases the per centage amount of hydrogen and

diminishes that of light carburetted hydrogen, thus decreasing the vitiating effect upon the atmosphere and the oppressive heat of the apartments in which the gas is consumed.

6. In addition to these positive advantages, the use of this process does not incur any additional expense in the working of the apparatus, or the wear and tear of retorts; it involves no alterations in the construction of furnaces and apparatus at present employed in gas manufactories conducted on the old system.

TABLE SHEWING THE QUANTITY OF COAL OR CANNEL REQUISITE FOR PRODUCING LIGHT EQUAL TO 1000 SPERM CANDLES, EACH BURNING 10 HOURS, AT THE RATE OF 120 GRS. PER HOUR.

Name of Coal.	Weight of Coal.	
	By old process.	By White's process.
Wigan cannel (Ince Hall)	465.1 lbs.	347.4 lbs.
Wigan cannel (Balcarres)	539.0 "	378.4 "
Boghead cannel	197.5 "	104.8 "
Lesmahago cannel	293.9 "	160.7 "
Newcastle cannel	443.9 "	396.7 "
Newcastle coal (Pelton)	745.7 "	——
Methyl cannel	421.4 "	202.0 "

SUMMARY OF EXPERIMENTAL RESULTS.

NAME OF COAL.	Cubic feet of gas per ton.		Illuminating power per ton in sperm candles.		Gain per ton by White's process.		Gain per cent. by White's process.	
	By old process.	By White's process.	By old process.	By White's process.	Quantity of gas in cubic feet.	Illuminating power in sperm candles.	Quantity of gas.	Illuminating power.
Wigan Cannel (Ince Hall) ...	10,900	16,120	4,816	6,448	5,220	1,632	47.9	33.9
Wigan Cannel (Balcarres) ...	10,440	15,500	4,156	5,920	5,060	1,764	48.5	42.4
Boghead Cannel	13,240	38,160	11,340	21,368	24,920	10,028	188.2	88.4
" 2nd experiment	....	51,720	....	20,688	38,480	9,348	290.6	82.4
Lesmahago Cannel	10,620	29,180	7,620	13,934	18,560	6,314	174.8	82.8
Methyl Cannel	9,560	26,400	5,316	11,088	16,840	5,772	176.2	108.6
Newcastle Cannel (Ramsay's)	10,300	15,020	5,046	5,646	4,720	600	45.8	11.2

[*Read January* 13*th*, 1852.]

VI.—*Notes on the Drift Deposits found near Blackpool.* By E. W. Binney.

[*Read February 24th,* 1852.]

In a communication to the Manchester Geological Society* made by the author in 1842, and printed by that society in its annual Report, a general description of the Lancashire and Cheshire drift deposits was given. It was there stated that few organic remains had been found in the deposits lying east of a line drawn from Preston to Congleton. In another paper printed in vol. viii. (new series) of this Society's Transactions, p. 204, he describes the drift found in and near Manchester at some length; but he makes no mention of the occurrence of fossil shells, none in fact having been met with by him in the beds alluded to. This difference in the distribution of organic remains in the drift is a subject well worthy of attention. It does not appear to be owing to the mechanical characters of the deposit; for while no shells have been met with in the sands and fine gravels of Kersal Moor, near Manchester, similar deposits at Bowdon afford them in considerable abundance. The till of Manchester, so far as it has at present been examined, is also destitute of fossil shells, while the same deposit in most places west of a line drawn from Preston to Runcorn yields them more or less.

We should scarcely expect to find delicate and fragile shells in a coarse gravel. If the mechanical characters of the deposits would account for the difference in preservation of the organic remains, the matter would be comparatively easy;

* Report of the Manchester Geological Society for 1843, p. 15.

but as we find that the sandy, gravelly, and clayey strata of the deposits have little to do with the occurrence of the fossils, probably the beds on and near the flanks of the Pennine chain may have been formed under conditions in some way less favourable to organic life, or else the shells of the mollusks of the then existing shells have been more frequently destroyed than those deposits more remote and lying near the present sea.*

Few places in Lancashire present greater facilities for studying the drift deposits, especially that part of them known by the name of the "*Till*," than the cliffs lying between Blackpool and Rossall, but up to this time little information upon them has been given to the public.

At p. 127 of the Rev. William Thornber's "History of Blackpool" is the following note, where that author, speaking of what he calls "that immense congeries of diluvium," states, "This marly deposit has never been perforated, the late attempt to find coal at Poulton Breck having failed, after boring 179 yards through marl commixed with gypsum, intersected at times with loamy sand and gravel."† This description is somewhat confused, but the beds of gypsum give pretty good evidence that other strata than those of the drift, or as the writer terms it, the diluvium, were penetrated. The beds of marl, loamy sand, and gravel, would appear to shew that the till and lower gravel had been met with, but, as gypsum is mentioned, it clearly shews that either the upper red marls of the trias, or the lower red marls of the permian, similar to those lying above the magnesian limestone, and below the upper new

* Since this paper was written, Mr. J. F. Bateman, Mem. Inst. C.E., F.G.S., has informed me that in making the Hollingworth reservoir, near Mottram in Longdendale, he met with the common cockspur shell (*Turritella terebra*) in considerable abundance. This place is about 450 feet above the level of the Irish sea, in a deep gorge running from the Pennine chain.

† *Manchester Guardian*, October, 1848.

red sandstone at Barrow Mouth near Whitehaven, had been reached under them; so the result of the boring cannot be depended upon as giving any correct idea of the thickness of the drift at or near Poulton Breck.

In speaking of these deposits, my observations will relate to the higher ground lying to the north of Blackpool, and not to the low peaty district lying to the south of that town.

The whole of the country appears to consist of the following beds, in a descending order, namely:—*

1st. A bed of brown clay, mixed with stones, used in brick-making, of about ....4ft. to 5ft.

2nd. A brownish coloured clay, containing stones and so many pieces of limestone as to render it unfit for the purpose of making bricks. It is called "good till" in the neighbourhood. The clay is often replaced by stratified beds of sand and gravel ....80ft.

3rd. A bed of silt of a lightish brown colour, containing a few pebbles, of about .... 2ft.

4th. Brownish coloured till, mixed with stones to the extent of nearly one-third of its whole mass, exposed ...30ft.

From the above it will, at once, appear that the drift deposits here are of a much simpler composition than the beds found near Manchester, and fully tabulated at p. 204 of the second paper before alluded to.† This probably may arise from some of the upper beds having been removed, and the inferior ones not being now exposed.

The cliff from Blackpool to Rossall varies in height from 40 to 90 feet, or thereabouts, and has an undulated character. In some of the hollows found in it are thin beds of peat lying

* The forest sand on the highest part of the cliff in Bispham is not noticed here, but it lies upon the brick yard clay. When this paper was read the author took it for a recent sand hill. He has not seen it in any other localities than this one, but it appears to occupy the samo position as the forest sand of Kersal Moor.

† Vol. viii. (second series) of the Memoirs of the Society, p. 204.

Section of the Drift from North Fell, Rossall, to Blackpool.

upon a light coloured silty clay, containing the remains of fresh water shells. These beds have evidently been formed in small swamps, by obstruction to the natural drainage. The most remarkable of them is that seen a little south of the Gynn, where the bed of peat is about 4 feet in thickness. In it are some hazel nuts, besides oak, birch, hazel, alder, and willow trees; but to my knowledge, up to the present time no fossil bones or other remains of animals have been met with in it, so as to render it worthy of a more detailed description.

The brownish coloured brick clay, No. 1, appears to cap the deposits the whole of the distance lying between Blackpool and North Fell, whether they consist of clay or sand and gravel.

The cliff at Blackpool, for the distance of about a mile, consists of clay and silt, with some isolated patches of stratified sand and gravel. Then comes about a mile and a half of stratified sand and gravel. The remainder of the distance to Rossall is composed of clay, with beds of silt at North Fell. See wood-cut, which, although on an exaggerated scale, will give some idea of the section.*

* The beds of sand and gravel dip much more in the wood-cut than when see in the natural section, where they appear almost level.

The order of super-position of the beds is not at all easy to make out, as there are such intercalations and graduations of one into another that at times it is impossible to speak with any degree of certainty.

Under the Royal Edward Hotel and at North Fell are beds of silt, forming arches dipping north and south, thus plainly shewing that this deposit has been subjected to considerable movements since its deposition. North of the Gynn the stratified beds of sand and gravel have a slight tendency to dip towards the south. Further on, in Bispham, the beds of gravel have been cemented together so as to form a hard conglomerate, which is much used in making rockeries and walls at Blackpool. Near the highest part of the cliff, a little south of the first farm house past the Gynn, No. 1 bed is capped with several yards of brownish coloured forest sand.

Having given the above general sketch, I shall now proceed to describe the several beds a little more in detail:—

No. 1 deposit much resembles the till in the neighbourhood of Manchester, except that it is of a rather browner colour, and effervesces more strongly when treated with acids. The upper portion of it, from its freedom from stones, is well adapted for brick-making, but after going down four or five feet, it contains many small fragments of limestone, and becomes more stony, and, consequently, unsuited for such purpose, although it makes good "till"* for the land, as the brick-makers say. In the brick-yard, near to the railway station, I found fragments of shells, but they are not very plentiful.

Upon carefully examining 100 specimens of the rocks thrown out of the clay by the workmen who were employed in digging it for brick-making, I found them as follows:—

* The origin of the term Till, in geology, no doubt arises from that deposit having been used by farmers as till for their land when it was marled.

	Total.	Angular.	Partly rounded.	Rounded.
Granites, greenstones, porphyries, &c.	49	17	20	12
Slates and silurians	32	5	16	11
Mountain limestones	6	3	2	1
Coal measures	9	4	3	2
New red sandstones and other superior rocks	4	1	2	1
	100	30	43	27

Six of the slate and silurian specimens were striated.

In the brick-yard near to the Royal Edward, on examination of 100 specimens, I found that the stones there thrown out of the clay were of the following descriptions, viz:—

Granites, greenstones, porphyries, &c.	42
Slates and silurians	44
Mountain limestones	4
Coal measures.........	8
New red sandstones and other superior rocks..............	2
	100

Their external characters were pretty much the same as in the table above described, of specimens from the brick-yard near to the railway station. Similar fragments of shells were likewise met with.

Deposit No. 2 is shewn on the face of the cliff under the bed last described. The clay to the depth of about 15 yards in some places is without much change of character, except that it is a little more stony. Isolated patches of stratified sand are met with in it. One or two of these may be seen in the face of the cliff below the Royal Edward, and by their soft nature cause the cliff to fall faster than in other places. Shells are more frequently met with in it than in the brick clay. Few marks of stratification can be traced in the deposit except where the beds of sand and fine gravel occur.

These are regularly stratified, contain numerous shells, and on towards Bispham, where they dip slightly to the south, appear to occupy the place of the bed of clay last described. At this place they consist of beds of coarse shingle and fine gravel, parted by layers of sand, scarcely to be distinguished from the pebbles found on the present beach at high water mark. Nearly all the stones are well rounded, and exhibit no marks of striæ. Most of them consist of granites, traps, and slates, with some few limestones, the softer stones, doubtless, having been destroyed by the action of water. At the highest part of the cliff, these beds of gravel are full 60 feet in thickness.

The greater portion of the shells hereinafter described were found by me in the deposits of sand and fine gravel near Bispham. Many of them are in a perfect condition, and shew every appearance of not having travelled or been conveyed from a distance. Most probably they lived near the place where they were found.

Mr. Thomas Glover, of Manchester, who was so kind as to examine my specimens, recognised the following:—

Univalves.

Nassa reticulata.—Not at the present time common on the Lancashire coast.

Purpura lapillus.—Common on the rocky shores of North Wales, and occasionally washed up at Blackpool.

Buccinum undatum.—Common at Blackpool.

Fusus Bamfius.—Not common on the Lancashire coast.

Rostellaria pes pelecani.—Occasionally washed up at Blackpool.

Triton erinaceus.—Common at Hilbre Island, and often washed up at Blackpool.

Littorina rudis.—Common at Blackpool.

Natica monilifera.—Found at Blackpool.

Nerita littoralis.—Common on the Lancashire coast on stones and sea weed.

Turritella terebra.—Common at Blackpool.

Dentalium entalis.—Often washed up at Blackpool.

Bivalves.

Venus gallina.—Often occurs at Blackpool.

Mactra subtruncata.—Common at Blackpool.

Mactra solida.—Common on the Lancashire coast.

Cardium edule.—Very common on the sand banks.

Cardium aculeatum.—Common at Blackpool.

Corbula inequivalvis.—Found occasionally at Blackpool.

Psammobia solidula.—Very common at Blackpool.

Ostrea edulis.—Often washed up at Blackpool.

Professor Edward Forbes* appears to have examined the drift deposits in some parts of Lancashire, as he notices the *solen siliqua, mactra lutraria,* a *dentalium,* found near Preston, and *nassa reticulata,* as occurring in them, elsewhere. However, he names no particular localities, except that of Preston. Doubtless, he did not visit Blackpool cliffs, or his well practised eye would soon have discovered the specimens above enumerated, and procured by me from that place.†

No. 3 is a stratified deposit of fine silt of a brownish colour, containing few stones. It is about two feet in thickness. Very few shells have, as yet, been found in it by me. The most remarkable feature which it presents, is its contorted appearance. In the cliff below the Royal Edward it forms a complete arch, dipping northwards and southwards; another flexure of a similar character, and dipping in like manner, is seen at North Fell, thus clearly shewing that it has been subject to considerable movements since its original deposition.‡ It is placed upon the brown stony till next described.

* On the connection between the distribution of the existing *Fauna* and *Flora* of the British Isles, and the geological changes which have affected their area, especially during the epoch of the Northern Drift, by Edward Forbes, F.R.S., L.S., G.S., Professor of Botany at King's College. London, vol. i. of the Memoirs of the Geological Survey of Great Britain, p. 367, et seq.

† Long after both the writing and reading of this paper, indeed, just before it went into the printer's hands, I obtained a sight of the Rev. William Thornber's very interesting historical and discriptive account of Blackpool, published as far back as 1837. At p. 128 the author says, "After most diligent inquiries I have never ascertained that any fossil bones, teeth, &c., of animals, terrestrial or marine, have ever been discovered imbedded in the marl; shells, however, in every repect similar to those now existing on the shore, namely, *buccinum undatum, purpura lapillus, nassa reticulata* and *macula, murex erinaceus, fusus antiquus, turritella terebra, littorina vulgaris, cardium, cohinatum,* and *edule, tellina solidula* and *tenuis, mactra solida* and *subtruncata,* &c., I have taken out of the cliffs and gravel strata."

‡ The silts beds at North Fell are three or four in number. The lowest part of

No. 4.—This consists of a brown clay, rather darker in colour than deposits Nos. 1 and 2 before described, and mingled with many stones stuck into it in all directions, some standing on their edges, others on their sides, and some again on their flat surfaces. The rocks are very numerous, and in the lower part of the cliff, below the Royal Edward, constitute fully one-third of the whole mass. Their average size is greater than in any of the other deposits, one specimen, a greenstone, now lying on the beach, evidently derived from this deposit, weighing nearly three tons. More than one-half of the whole of the stones are angular, others are partly angular, and few are rounded. Scarcely a slate, or carboniferous rock of six inches in diameter, can be found without some marks of striæ upon it. These run nearly always parallel to the major axis of the stone. The hard greenstones and porphyries do not so frequently shew striæ as the other specimens do. The kind of rocks found in this deposit is difficult to get at by counting in the cliff, but 100 specimens each of which was not less than the size of my fist, taken promiscuously from the shingle lying on the beach below, and which had, beyond doubt, been derived from the cliff, were as follows :—

New red sandstone	1
Carboniferous series—10 limestones and 4 gritstones	14
Silurians and slates	49
Granites, greenstones, porphyries, &c.	36

In the till found in the neighbourhood of Manchester, specimens of magnesian limestone and new red sandstone are met with. At Blackpool, in that deposit I have not yet met with a specimen of the former rock, but many of the latter, and one of the permian conglomerate, have been found. An inte-

the bed of clay No. 2, just above the bed of silt at the south end of the arch below the Royal Edward, is, for the thickness of about 10 inches, quite paved with stones, when compared with the average quantity found in the deposit. The bed of silt appears to form the upper boundary of the stony till next described, and, like that deposit, is only exposed to a limited extent.

resting fact is, the quantity of both granular and fibrous gypsum and waterstone from the upper red marls of the trias. These I have seldom found previously in the till of Lancashire. But the greatest novelties, in the shape of rocks, are two specimens of lias, containing the gryphæa *incurva* and pieces of chalk flint. These I have never yet found in Lancashire, except at Blackpool, nor have I ever heard of their having been noticed by other parties.

The shells met with in this deposit are, on the whole, much more numerous than those found in Nos. 1 and 2, but they are nearly all more or less broken. I have found specimens of the genera *turritella, nassa, buccinum, dentalium, nucula, cardium, tellina,* and *psammobia,* most of which had been previously found by my friend, Mr. Robert Harkness, in the till, near Ormskirk.

The sea appears to be encroaching on the cliff composed of till, where it is not protected, at the rate of about one yard every year on the average. At places where the sand and gravel beds occur, its attacks are more rapid. This destruction of the land seems to have gone on for centuries, as the low water mark, at spring tides, shows numerous large blocks of stone, evidently derived from the till and gravel, when the boundary of the cliff was nearly at that point. Some of the pieces of cemented gravel, like the Pennystone, are of immense size.

During the last year, the beds of sand and fine gravel (No. 2) in the cliff between the Royal Edward and Dickson's Hotel, have been exposed far more than they had been previously supposed to exist in that neighbourhood; and if the sea is allowed to continue its attacks, without any attempt being made to resist it, the destruction of land will, most probably, be much greater than at the rate at which it has been destroyed during the last ten years.

As previously stated, the deposit, No. 2, in Bispham, bears every resemblance to an old beach of shingle, like those at present forming on the shore below, but the till No. 4 presents a very different appearance, and bears no analogy to anything now in the course of formation along the line of the neighbouring coast. The angular and striated characters of the rocks mingled together promiscuously, large and small, without any arrangement, some upon their edges, others inclined, and some again quite flat, must puzzle any observer to account for them by the action of waves or ordinary currents of water. Upon comparing them with the stones now found lying upon the beach below, it is quite evident that the rocks are of the same kind, and that all the latter have been derived from the cliffs; but the action of waves, during years, has evidently worn away the sharp edges, and defaced the striæ from most of the specimens. Few persons, however, are at all aware how short a space of time suffices to round the most sharp-edged piece of hard greenstone, washed out of the cliff and subjected to the action of the waves below. A mass of till full of angular stones being undermined by the sea, falls, the clay is soon washed away, and the stones are thus brought within the action of the water, and, in one short month, the waves have so effectually done their work of attrition that the rocks are as round as if they had been rolled about for years.

An opinion expressed by me, in a paper on drift deposits previously referred to, as to the till of Lancashire having been deposited at the bottom of a sea in which floated numerous icebergs, I am more and more confirmed in. However the beds of sand and shingle found above the till may answer to the term "raised beach," the till itself bears no evidence of any such condition, but ought rather to be termed a raised bottom. It has thus been affected by considerable movements since its deposition, and much twisted and contorted, as numerous sections of it and the silt sufficiently prove. Many parts of it appear to have been subjected to much erosion and denudation prior to the deposition of the beds now covering it. Most of the hard rocks in the beds of gravel are of the same kinds as those found in the till, however much their external characters may have been altered. In all probability, therefore, the former is merely the *debris* of the latter.

On the upraising of the till from the bottom of the sea, its surface would soon become liable to the abrading action of the waves, and thus furnish rocks for the sands brought by currents from the neighbouring new red sandstone coast, just as the present cliffs furnish the pebbles for the shingle beaches at Blackpool.

The rocks in the till have, no doubt, come from a considerable distance, especially the lias and chalk specimens, which are not now found *in situ* nearer than the north-east coast of Ireland.

The rocks in the till at Manchester, taken on three different sides of that town, gave mean results as follows :*—

	Total.	Angular.	Partly Rounded.	Rounded.
Granites, greenstones, and other igneous rocks	21	5	10	6
Slates and silurians	21	3.66	9	8.33
Mountain limestones	6	1	3	2
Coal measures	49.33	25.33	19	5
New red sandstones	2.66	2	0.66	0
Striated rocks	1.66			

In the brick-yard near the railway station at Blackpool, the rocks were as follows :—

	Total.	Angular.	Partly Rounded.	Rounded.
Granites, greenstones, and other igneous rocks	49	17	20	12
Slates and silurians	32	5	16	11
Mountain limestones	6	3	2	1
Coal measures	9	4	3	1
New red sandstone and superior rocks	4	1	2	1
Striated rocks	6 slates and silurians.			

* Memoirs of the Lit. and Phil. Society of Manchester, vol. viii. (new series) p. 224.

The above tables shew that the surface till of Manchester differs from that of Blackpool in having a much smaller proportion of granites, igneous rocks, slates, silurians, and striated stones, and a much greater proportion of coal measure rocks. This, as might have been expected, if we assume a force moving, from the north-west to the south-east, for one-half the distance between Blackpool and Manchester, as may be seen by looking at a geological map, is over the great Lancashire coal-field. The two rival theories put forth to account for the phenomena found in the till, namely, the iceberg and wave of translation, or a combination of them both, might each account for the difference; but the beds of stratified silt, both at Manchester and Blackpool, present appearances which no wave of translation can account for, as they must have been deposited in moderately still water. The striated and polished surfaces of the stones seem to indicate the action of glaciers, or rubbing of a mass of ground ice over a rocky bottom.

The lower bed of till, composed nearly of one-third its bulk of stones, presents appearances such as are not seen in the upper beds either at Manchester or Blackpool, for the majority of the rocks found in it bear marks of striæ, or have polished surfaces. Some of them are stuck into the clay right on their edges, and others at every variety of angle. Although the rocks here are far more numerous than in the till at Manchester, or in any of the beds superior to the silt at Blackpool, still I have met with more large specimens, say those exceeding two tons, at the former place than at Blackpool.

With the exception of the lias and chalk specimens, the coasts of Cumberland and Furness could supply nearly all the rocks now found in the deposit. But how have they been carried to the place where they are now met with, scored, polished, angular, partly rounded, and placed on end, as they now are? Their present conditions seem to require the conjoint action of glaciers and icebergs to produce them. Now let us suppose a glacier filling the deep valley of the Duddon, or any of the other valleys of Cumberland, and extending from the mountain sides down into the sea, until part of it broke off and floated away across Morecambe Bay as an iceberg, (a circumstance of common occurrence with the glaciers of Spitzbergen and other northern countries,) and afterwards melted or toppled over, having deposited its cargo of rocks and debris on the bottom of a sea composed of soft mud. This would account for most of the phenomena we witness in the till. The Scotch and Irish rocks might have been brought by a stray iceberg conveying specimens of stones from those more remote districts. I mention this opinion, formed after a careful consideration of the appearances observed in examining the bed of stony till, but, of course, it will not account for the sand and shingle beds, which are evidently nothing more than old littoral deposits. The beds of clay, containing pebbles Nos. 1 and 2, do not afford such strong proofs of glacial and iceberg action as deposit No. 4, but still they exhibit more appearances of having been deposited at the bottom of a sea in which icebergs floated than under any other condition.

The deposit No. 4 is by far the greatest in thickness, although very little of it is exposed at Blackpool or North Fell under the beds of silt, which I think might be termed its upper boundary.

The two anticlinal axes of the bed of silt lead me to suppose that the deposits Nos. 1 and 2 lie in a synclinal axis of it, which extends from near the Gynn to North Fell. The dip of the beds of gravel may scarcely bear out this view, but that is by no means so great as appears in the section, as I previously stated; in fact, in some places it takes a northerly dip, and at others is so small as scarcely to be appreciated; so I have little doubt of the beds of silt and stony till underlying the whole of the gravel between the two last named places. It appears to me the till was once an old sea bottom. Upon its being elevated, it would soon be exposed to the action of currents of water, and much eroded and washed away. In the hollows caused by such agencies, the littoral deposits of sand and gravel may have been deposited. The land then appears to have subsided and icebergs and glaciers again come into operation, although to a less extent than on the first occasion before alluded to, as the number of rocks, and especially such as are scored and striated, is far less than those met with in No. 4. Subsequently, the whole district has been elevated from the sea into its present position.

The more that the phenomena of the drift deposits are studied, the more we must be convinced that so far from having been formed in a short period of time, as was once the generally received opinion, when they were erroneously attributed to the Noachian deluge, they have occupied ages in their formation; during which, they have been more than once raised and depressed, and considerable portions of them washed away and replaced by other deposits. These changes of level, there appears to be no reason for believing were of a more speedy nature than the slow and gradual motions of the land we see going forward upon the face of the globe at the present time. The sands and gravels of the deposits are easily recognised as ancient strands and beaches; but the beds of till present us with no such appearances, presenting every indication of having been once the bottoms of ancient seas, in which floated various rocks freighted with numerous icebergs, which, on being dissolved or toppled over, deposited their loads on the soft mud below.

VII.—*Some account of the Floods which occurred at the Manchester Waterworks in the month of February,* 1852.

By JOHN FREDERIC BATEMAN, F.G.S., Mem. Inst. C.E.

[*Read March* 23*rd*, 1852.]

IN the year 1848, in giving to the society a continuation of the periodical reports upon the fall of rain, the Valley of Longdendale, from which the town of Manchester is to be supplied with water, was shortly described, and such observations as had at that time been made upon the rain in the district, and the quantity of water which flowed from the ground, also accompanied the paper.

Since that period most of the observations upon the fall of rain have been continued, and the vast works for the storage and conveyance of water which were then only in contemplation have been in great measure executed, and are now rapidly advancing towards completion.

In the main valley of the Longdendale district, down which flows the river Etherow, three large reservoirs are now constructing, filling the valley for nearly five miles in length. These three reservoirs will contain, when finished, about 516,000,000 cubic feet of water, and will cover about 344 statute acres of ground. The Woodhead Reservoir, which is the highest of the series, is formed by an embankment of 90 feet; it is about a mile and two-thirds in length, and receives the water naturally draining from about 7,500 acres of high mountain land. The Torside Reservoir, the middle one and the largest of the three, with an embankment of 100 feet in height, and the Rhodes Wood Reservoir, immediately below, with an 80 feet bank, have together an additional collecting ground of about 7,900 acres, making the total drainage to these three reservoirs 15,400 statute acres. The Torside Reservoir is nearly two miles in length, and the Rhodes Wood Reservoir about a mile.

The following are some particulars of the reservoirs :—

Reservoir.	Embankment.		Reservoir.			
	Greatest height.	Contents.	Area.			Capacity.
	Feet.	Cubic Yards.	A.	R.	P.	Cubic Feet.
Woodhead	90	152,707	134	3	18	198,725,693
Torside.....................	100	399,129	160	0	6	236,659,573
Rhodes Wood	80	263,248	54	0	34	80,255,910
		815,084	349	0	18	515,641,176

In the execution of works of this magnitude, placed across a valley down which the ordinary water and impetuous floods of so large a tract of mountain land are hurried with rapidity, it is very important to provide ample means for the safe passage of the water. Observations had accordingly been made with reference to this particular object for some years previous to the laying out of the works. From these observations it appeared that it was not likely that many floods would exceed 10 feet per second for every 100 acres of collecting ground, and that provision for 15 feet per second would be ample. The Woodhead Reservoir was the first which was laid out for construction, and in designing the side channels or watercourses for carrying away the floods during the early progress of the embankment across the river course, they were formed of such dimensions as would, with the assistance of a large discharge pipe under the embankment, pass off safely about 1,000 cubic feet of water per second, being at the rate of about 15 feet per second for every 100 acres.

The ground was first broken for the construction of this reservoir in September, 1848; and, in the following month, before much progress had been made, a very heavy flood occurred in the neighbourhood of Blackburn, which was the cause of a lamentable accident at Darwen, near that town, by the bursting of a private reservoir and the consequent loss of twelve or thirteen lives. The volume of this flood I was enabled to determine with tolerable approximation to accuracy, by means of the reservoirs of the Blackburn waterworks, which were then just completed. It exceeded 25 feet per second for every 100 acres of collecting ground. Had a similar heavy fall of rain occurred in the upper part of the Longdendale district, it would have produced a flood of about 2,000 cubic feet per second at the Woodhead Reservoir,—nearly double the volume which had been provided for.

Acting upon the experience and information thus acquired, an additional discharge pipe was immediately introduced, and the flood watercourse was enlarged as far as practicable, so that a flood of 1,500 feet per second could be passed with safety, with 16 feet of pressure upon the pipes. As the embankment gradually exceeded that height in the course of construction, the means of storage behind the banks would be increased; and by the greater pressure upon the pipes more water also could be discharged, and in these ways provision would be made for the safe passage of a still larger quantity. On several occasions, in the course of the following eight or ten months, the floods amounted to 1,800 or 2,000 feet per second; shewing the wisdom, and indeed the necessity of such a provision having been made.

Early in October, 1849, just twelve months after the Blackburn flood, which had afforded such valuable information, the flood watercourse having been completed, the discharge pipes laid, and every arrangement made for proceeding with the embankment of the reservoir, the inner tie of that bank was raised to a height of about 16 feet, so as to give that amount of pressure on the discharge pipes in case of necessity. On the 7th a very heavy fall of rain, accompanied with a hurricane from the north-east, occasioned a flood which set at nought all previous calculations. When at its highest it amounted to upwards of 4,000 cubic feet per second, being at the rate of upwards of 50 feet per second for every 100 acres. After attaining this height, it flowed for the following three hours at an average of 1,800 feet per second. A weir on the watercourse across the Heyden Brook, which was not quite finished, but which had been considered sufficiently so to secure the safe passage of the water, was absolutely beaten down by the force of wind and water, and a breach being made through which the water passed, the watercourse was thus rendered useless. The water poured into the basin of the reservoir, and speedily overtopped the newly-formed piece of embankment. It had been raised to a height of 24 feet, and was raised 3 feet more during the progress of the flood, so that when the water reached the top it was 27 feet high. The bank was not long in being cut down, and a quantity of water amounting to about 14,000,000 cubic feet was set at once at liberty. For a short distance it carried all before it, and did more or less damage for four or five miles down the river. No serious mischief, however, was sustained, and happily no lives were lost. The quantity of water which was impounded at the time of the accident was about equal to that contained in the unfortunate Bilbury Reservoir, near Holmfirth, which burst on the 5th of February and did such fearful injury in the valley below. The difference in the circumstances of the two cases easily accounts for the difference in the two results. The depth of the water in the Bilbury Reservoir was about 80 feet; at Woodhead it was 27 feet only. The embankment of the Bilbury Reservoir, owing to its peculiar construction, gave way in a great mass at once, and the valley into which this mighty wall of waters was instantaneously hurled is a steep and narrow ravine, down which the water would continue to flow with impetuous velocity. The Woodhead valley, on the contrary, has a much more gentle slope, and is much wider throughout, occasionally expanding into level flats of considerable width. Consequently the velocity of the water would be speedily diminished, and its volume absorbed by filling up the flat ground on each side. The damage was comparatively trifling, being all repaired or compensated for by the payment of little more than £2,000.

The embankment was restored, and no further flood of any consequence occurred until the work was far advanced. The remaining reservoirs in the valley had been some time previously laid out and commenced, and abundant provision had been made at these new reservoirs for the passage of the floods.

Of the various rain gauges which are placed in the district, one only is registered daily, viz., that at Crowden Hall, the others being placed on the heights in somewhat inaccessible situations, and only observed weekly or monthly. The quantity of water which was received into the Woodhead Reservoir, or passed by the flood watercourse on the occasion of the flood alluded to, must have exceeded 3 inches in the 24 hours, or rather, in the 17 or 18 hours during which the rain fell most heavily, and yet the depth registered at Crowden Hall was only $1\frac{4}{10}$ inch. Crowden Hall is about two-thirds of a mile below the Woodhead embankment, and the heaviest portion of the rain must therefore have been on the hills above the reservoir. At the Redmires Reservoir of the Sheffield Waterworks, on the same day, there were registered nearly $2\frac{1}{2}$ inches. The distance from Woodhead, in a direct line south-east, is $13\frac{1}{4}$ miles.

The fall of rain in 1849 was about an average, there being at Crowden Hall $54\frac{4}{10}$ inches: 1850 was considerably below the average, the rain being only $44\frac{1}{10}$; and singularly enough, almost the only heavy flood which occurred in the course of the year was on the 7th and 8th October, the anniversary of the destructive flood of the previous year, and (within a few days) of the Blackburn flood of 1848.

The year 1851 was still more below the average, the rain at Crowden being only $40\frac{1}{10}$ inches. In this year the only heavy flood occurred about the 8th and 9th June.

The fall of rain, as registered at the various rain gauges in the district since the end of 1847, up to which time they are recorded in my last paper to the Society, is as follows:—

1848.	Brushes, 480 ft.	Windyate Edge, 1,700 ft.	Crowden Hall, 700 ft.	Bakes Moss, 1,620 ft.	Butterley Moss, 1,750 ft.	Mean of all the observations.	Mean, omitting Brushes.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inehes.
January......	2.0	1.7	1.1	...	1.6	1.6	1.5
February ...	8.0	9.2	8.2	...	10.1	8.9	9.2
March	4.7	4.4	5.5	...	4.9	4.9	4.9
April	1.5	2.1	2.6	...	2.9	2.3	2.5
May	1.2	1.8	1.0	2.1	1.0	1.4	1.5
June	5.3	6.1	6.8	7.0	6.2	6.3	6.5
July	4.2	4.2	4.6	4.4	2.4	4.0	3.9
August	5.8	7.5	7.0	7.8	5.8	6.8	7.0
September...	4.2	5.4	4.3	5.1	3.4	4.5	4.5
October	5.8	8.3	8.0	6.0	7.5	7.1	7.5
November....	2.6	3.2	3.1	4.0	2.3	3.0	3.1
December....	3.6	3.8	3.7	2.8	3.7	3.5	3.5
Total	48.9	57.7	55.9	...	51.8	52.8	55.1

1849.	Brushes, 480 ft.	Windyate Edge, 1,700 ft.	Crowden Hall, 700 ft.	Black Clough, 1,700 ft	Butterley Moss, 1,750 ft.	Mean of all the observations.	Mean, omitting Brushes.
	Inches.	Inches	Inches.	Inches.	Inches.	Inches.	Inches.
January......	5 3	6.3	8.2	6.0	...	6.4	6.8
February ...	1.5	2.4	2.4	2.0	...	2.1	2.3
March	.6	1.0	1.5	2.0	...	1.3	1.5
April	1.4	2.5	3.0	3.0	...	2.5	2.8
May	3.0	3.4	2.8	2.5	...	2.9	2.9
June	1.8	2.1	1.7	3.0	...	2.2	2.3
July	7.5	8.8	7.8	6.1	...	7.5	7.5
August	4.2	4.5	5.4	4.0	...	4.5	4.6
September...	4.8	6.4	4.7	6.3	...	5.5	5.8
October	4.1	6.3	7.0	8.7	...	6.5	7.3
November....	4.7	5.8	5.1	4.0	...	4.9	5.0
December....	3.8	4.7	5.1	4.6	...	4.6	4.8
Total	42.7	54.2	54.7	52.2	...	50.9	53.6

1850.	Brushes, 480 ft.	Windyate Edge. 1,700 ft.	Crowden Hall, 700 ft.	Black Clough, 1,700 ft.	Butterley Moss, 17,50 ft.	Mean of all the observations.	Mean, omitting Brushes.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
January	2.9	4.5	3.8	4.2	2.8	3.6	3.8
February ...	3.4	5.0	4.4	4.6	2.8	4.0	4.2
March	0.6	0.8	1.1	3.5	0.7	1.3	1.5
April	2.4	3 5	4.0	4.0	3.0	3.4	3.6
May	1.5	2.1	2.0	1.5	1.2	1.7	1.7
June	1.5	2.9	3.4	3.5	2.3	2.7	3.0
July	3.7	5.5	4.8	7.9	4.1	5.2	5.6
August	4.0	6.6	3.2	5.9	3.0	4.5	4.7
September...	1.5	2.6	1.8	0.7	1.2	1.6	1.6
October	3.6	6.4	6.5	5.5	4.0	5.2	5.6
November ...	4.3	7.7	7.8	7.5	3.0	6.1	6.5
December....	2.4	2.9	1.3	4.0	3.4	2.8	2.9
Total	31.8	50.5	44.1	52.7	31.5	42.1	44.7

1851.	Brushes, 480 ft.	Windyate Edge, 1,700 ft.	Crowden Hall, 700 ft.	Black Clough, 1,700 ft.	Butterley Moss. 1,750 ft.	Mean of all the observations.	Mean, omitting Brushes.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
January	2.9	3.1	2.5	3.8	4.3	3.3	3.4
February ...	2.1	2.2	3.0	2.5	2.6	2.5	2.8
March	3.6	3.7	4.1	4.5	2.9	3.8	3.8
April	0.4	1.5	1.8	2.8	1.9	1.7	2.0
May	1.5	1.9	3.0	3.5	3.2	2.6	2.9
June	5.8	6.6	6.3	5.9	6.0	6.1	6.2
July	3.7	4.6	3.8	1.4	4.7	3.6	3.6
August	4.1	4.2	4.2	5.3	3.4	4.2	4.2
September...	1.8	1.9	3.0	2.6	2.5	2.4	2.5
October	3.6	4.6	4.9	4.0	5.3	4.5	4.7
November ...	1.6	1.6	2.7	3.2	1.6	2.1	2.2
December ...	1.5	2.3	0.8	1.5	1.4	1.5	1.5
Total	32.6	38.2	40.1	41.0	39.8	38.3	39.8

Many of the mountain gauges have been stolen, removed, or tampered with, and I am afraid that the only ones upon which much dependence can be placed are those at Brushes, Windyate Edge, and Crowden Hall. When the works are completed the reservoirs themselves will be the best gauges.

Before giving the particulars of the floods which occurred in the early part of last month, it will be well to describe the position of the reservoirs, and the means which they afforded of ascertaining with accuracy the quantity of water which was received. It has hitherto seldom or perhaps never happened that a single heavy flood or fall of rain has been so accurately observed. This fact is my apology for endeavouring to place the particulars on record.

In the early progress of the formation of the embankments, provision was made at each reservoir for the passage of the floods by the construction of a capacious cut or canal called a flood-watercourse, above the level of the reservoirs, as already described. This provision was adopted and employed for the purpose intended both at the Woodhead and Torside Reservoirs, until the embankments at each place were advanced to a height at which it was deemed safe to dispense with the aid of the watercourses, and to depend for safety upon the storage which the reservoirs afforded, and the means of discharge provided by the two lines of 4 feet pipes which had been introduced in all the embankments. It was necessary also, as the work advanced, to cut across or destroy the watercourses for the purpose of completing what are technically called puddle trenches, which are deep trenches of retentive material, sunk for the reception of the clay or puddle employed to render the whole water-tight. The permanent waste weirs of the reservoirs also had to be constructed on the site of the flood water-channels, for which purpose likewise they had to be dispensed with.

The Rhodes Wood Reservoir, the lowest of the three, would have been similarly provided with a bye-channel for the waste water, but delay had unavoidably arisen by the channel to be formed over an ancient land-slip. This land-slip was well known, and had been long moving slowly. At the turnpike road on the north side of the valley, it had moved about three feet in thirteen years; but the speed of its motion was materially increased on being cut into for the purpose of forming the watercourse. Means had to be resorted to for arresting its further progress, and the work was consequently so much delayed that this watercourse is not yet completed.

Ample provision, however, for the passage of the floods at the Rhodes Wood Reservoir was made by leaving a gap in the embankment, which remained open until the two higher reservoirs were so far advanced as to be able to hold all the water which could not be passed through the two pipes of the Rhodes Wood bank. The gap in this embankment was then closed, and the embankment raised as rapidly as possible.

This step, however, was not taken, nor indeed any other which involved the necessity of subsequently depending upon the power of impounding in the reservoirs for security against damage by floods, without first considering what depth of rain could be safely stored in the reservoirs or passed through the pipes.

Three inches of rain coming off the ground in 24 hours, with a considerable margin for its continuance or for a heavier fall, was adopted as the base of our calculations, being considered as the maximum amount which need be provided for. This quantity the works were always in a condition to receive and pass with safety. It was thought, from previous observation, that it was exceedingly unlikely that a larger fall of rain than this could occur over the whole district, and it was expected that should such a fall take place the rain would then cease, and the reservoirs might be emptied for the reception of another flood.

Such, then, being the provision which had been made, and the grounds for believing such provision to be sufficient, the position of the reservoirs at the commencement of the late floods was as follows:—

The Woodhead embankment was raised to its full height, but it was not deemed prudent to fill the reservoir above a certain level, in consequence of operations which were going on to render the hill side into which the embankment had to be tied perfectly water-tight.

The Torside embankment was far advanced; but here also operations were being carried on to render the reservoir water-tight, which rendered it undesirable to impound water to a greater depth than about 30 feet.

At Rhodes Wood Reservoir, which it will be remembered is the lowest in the valley, the embankment was sufficiently advanced to allow water to be impounded 40 feet in depth. Through the pipes of this reservoir *all* the water had to be passed, and therefore by calculating the quantity which could be discharged through them according as the pressure varied during the progress of the flood, the whole quantity could be precisely ascertained.

It is well known that the velocity with which water is discharged through pipes or through apertures, varies as the square root of the pressure or head of water above the opening.

The proper co-efficient for finding the mean velocity of the water discharged varies according to the character of the opening.

The theoretical velocity due to the height is the same as that of falling bodies, which is ascertained by multiplying the square root of the height by the co-efficient 8.0458.

The co-efficient, however, for finding the actual velocity varies from 5 to 7; that generally used for ordinary openings being from 5.1 to 5.4.

Should the water approach the opening with any velocity, that must be taken into account, and a higher co-efficient employed.

To determine the quantity which will be discharged through pipes, different formulæ have to be employed, for the friction along the sides of the pipe forms a material element in retarding the velocity of the water. Amongst many valuable rules deduced from the experiments of various eminent mathematicians and scientific observers, probably the simplest for calculating this velocity, and perhaps that most generally adopted, is one by Dr. Young from Eytelwein's Hydraulics, and is as follows:—

"Multiply 2,500 times the diameter of the pipe in feet by the height in feet, and divide the product by the length in feet, added to 50 times the diameter,—then the square root of the quotient will be the velocity of discharge in feet per second."

This rule is a tolerably safe one in practice. I believe it to be under the truth for large pipes and high velocities; and it requires to be used with judgment in determining the discharge by small pipes, where the system is complex.

The circumstances under which the water was discharged from the Rhodes Wood Reservoir were so far complicated as to render the determination of the proper co-efficient a question of some difficulty.

Two pipes, each 4 feet in diameter, and 303 and 370 feet respectively in length, were diminished at the outer end to 3 feet, the water being finally passed through a pipe of that diameter for about 20 feet in length, and through a 3-feet valve, divided into two compartments. One pipe branched into two at the end, having a valve at each branch, and through both of which water was discharged. The pipe is too large and the circumstances too complex to admit of the application of the rule for calculating the discharge through pipes. The water would approach the opening with considerable velocity, acquired in its passage through the 4-feet pipe, and therefore, rather a higher co-efficient than that usually employed for finding the velocity through openings, should be adopted. From a consideration of all these circumstances, and from other observations upon the actual quantity of water discharged, the co-efficient adopted was 5.5; and this may be rather lower than it ought to be.

With this co-efficient, however, the calculations came out, as will be shortly shewn.

The month of January had been marked by a considerable fall of rain, and at the end of the month the ground was thoroughly saturated, the streams and springs yielding considerably above their ordinary quantity of water. The heavy rain which was the cause of so many serious and destructive floods commenced on the morning of Wednesday the 4th of February, and, (with slight cessation on Friday and Saturday,) continued with little intermission till the morning of Monday the 9th.

On the morning of the 4th the Woodhead Reservoir contained about 24,000,000 cubic feet of water, being about 34 feet deep, and 47 feet below the top water level. The Torside and Rhodes Wood Reservoirs were both empty. Early in the day the rain had so swollen the streams that the discharge pipes could no longer pass the water, and it began to impound rapidly in all the reservoirs. By Thursday night the water had attained its greatest height, the depth in the Woodhead Reservoir being about 62 feet, and in the Torside and Rhodes Wood Reservoirs, about 30 feet. The quantity impounded was about 103,000,000 cubic feet in the Woodhead reservoir, 14,000,000 in Torside, and 15,000,000 cubic feet in Rhodes Wood Reservoir.

From Thursday night the water gradually lowered till Saturday night, by which time the water had been drawn down about 9 feet in the Woodhead Reservoir, and about 5 feet on the average, in each of the others. The quantity discharged through the pipes of the Rhodes Wood Reservoir during this period had averaged from 450 to 500 cubic feet per second. For 24 hours together, from Wednesday morning to Thursday morning, the flood had averaged 1,520 cubic feet per second, being, when at its highest, from 3,600 to 4,000 feet per second. This was from a tract of country, it will be remembered, of 15,400 statute acres, and amounts to about 25 cubic feet per second from every 100 acres of ground. The ordinary flow of the stream varies from 15 to 30 feet per second. The water which was passed through the pipes or was impounded in the reservoirs during this period, was equal to a depth over the whole collecting ground of $2\frac{4}{10}$ inches.

On Saturday night it again commenced raining heavily, and continued until two o'clock on Sunday afternoon. At this time the rain ceased for a couple of hours; but the streams were swollen to a volume of nearly 3,000 cubic feet per second, while the utmost that could be discharged through the pipes of the Rhodes Wood Reservoir was under 600 feet per second. At four o'clock it again commenced raining with the same intensity as before, with every appearance of its continuing through the night. At this moment the prospect was one of great anxiety. Thousands of persons, alarmed by the dreadful catastrophe at Holmfirth, had passed up the valley in the course of the day, in all the pouring rain, to visit the scene of that calamity; or had assembled on the banks of the waterworks reservoirs, anxiously watching the progress of the flood, and waiting to see the final burst which the majority anticipated. Towards the evening vehicles of all kinds, and horsemen at full gallop, despatched by anxious parties below to make inquiries, were constantly arriving; and, indeed, to the Engineer confident in the stability of his work, and in the provision which had been made for the safe passage of the waters, it was matter of no light concern or slight responsibility. There remained only six or seven hours safe storage for such rain as was at that moment falling; after the expiration of which time, the valves of the Woodhead Reservoir must have been opened to prevent the further rise of water in that reservoir, and the water allowed to pass over the puddle of the Torside bank, through a mass of rock which had been heaped together in the formation of the bank, with a view to such a contingency, and over the top of the Rhodes Wood bank, through a large timber shoot, which had been hastily but substantially prepared during the progress of the flood, for the purpose of safely passing the water to the river below.

In all probability, these preparations would have been sufficient to have sustained a flood of one or two days longer continuance; but they must have been put to the test in the middle of the night, in extreme darkness, when it would have been impossible to have seen what was going on, or how to meet or remedy any defect which might have occurred. The work of destruction, at the worst, would have been very slow and gradual, from the excellent manner in which the embankment had been formed, and the retentive and coherent character of the great bulk of the material. Happily, there was no occasion for the trial. The sun went down red and glowing with a murky grandeur, dimly seen beneath the clouds, which, though breaking and clearing to the west, were then pouring down their contents in torrents at the place at which we stood. The rain gradually abated, and nearly ceased before six o'clock, and I was satisfied that the worst was over and that all imminent danger was passed.

Heavy flying showers continued through the night; but at day-break the following morning it appeared to be again setting in for continued rain. The wind up to this time, during the whole storm, had been blowing steadily from the south-west, but it now gradually veered round to the north, and I then felt perfect confidence that the weather was taking up, notwithstanding the lowering and gloomy appearance of the morning. The rain subsequently ceased before noon, and by the end of the week the weather was quite settled and fine, the barometer gradually rising, and then remaining steadily fixed at an unusual height.

The water which was impounded in the reservoirs when the rain ceased on the morning of Monday the 9th, was about 160,000,000 cubic feet, of which nearly 140,000,000 were due to the rains of the previous week. By noon of the 13th the whole of this water had been discharged, and the reservoirs brought down to the same condition in which they were on the morning of the 3rd, when the rain commenced. The quantity discharged through the pipes of the Rhodes Wood

Reservoir, through which, as has been before observed, the whole had to be passed, was as follows:—

	Cubic feet.
From nine o'clock on the morning of the 4th to 2 p.m. same day, 5 hours, at 300 feet per second...............	5,400,000
From 2 p.m. to 12 p.m., 400 feet per second for 10 hours	14,832,000
From 12 p.m. 4th, to 9 a.m. 5th, 450 feet per second for 9 hours	14,580,000
From 9 a.m. 5th, to 7 p.m. 7th, 58 hours, at 450 feet per second	93,960,000
From 7 p.m. 7th, to 7 p.m. 8th, mean discharge 500 feet per second, 24 hours	21,600,000
From 7 p.m. 8th, to noon 12th, 89 hours, at 550 feet per second...	176,220,000
From noon 12th to noon 13th, 24 hours, at 450 feet per second...	38,880,000
Total...........................	365,472,000

The quantity of water discharged was equal to a depth of 6½ inches over the whole surface of the collecting ground, averaging nearly 1¼ inch per day for the 5½ days during which the rain lasted.

The rain at Crowden Hall from the evening of the 3rd to noon on the 9th, subsequently to which no material fall of rain occurred during the period that the reservoirs were being emptied, was $5\frac{1}{10}$ inches. To determine the precise quantity of water due to the fall of rain, something must be deducted for the yield of the streams, supposing no rain had fallen. Their average volume, swollen as they were by previous rain, would have been about 60 cubic feet per second, which, for 9 days and 3 hours would have amounted to 59,304,000 cubic feet,—equal to about an inch in depth over the collecting ground, leaving the nett quantity of water due to the rain 5½ inches,—being $\frac{4}{10}$ of an inch more than the rain shewn by the Crowden Hall rain gauge.

The results just given from calculations upon the discharge through the pipes, I believe to be very near the truth—rather under than over; but the Woodhead Reservoir afforded means for still more accurate observation. Here nearly all the water which reached the reservoir was impounded; and, as the capacity of each reservoir had been previously ascertained by careful survey and measurement, for every foot in depth, there can be no doubt as to the quantity of water received.

From eleven o'clock on the morning of the 4th till twelve o'clock at midnight on the 5th, a period of 37 hours, the quantity of water impounded in the reservoir was 75,720,000 cubic feet, and the quantity discharged 12,168,000,—making the total quantity received 87,888,000 cubic feet = $3\frac{1}{4}$ inches of rain over the drainage ground of the reservoir.

From eleven o'clock on the morning of the 4th to the same hour on the morning of the 5th, the quantity impounded was 62,000,000 cubic feet, and the quantity discharged 3,528,000, making the total quantity received in 24 hours, from 7,500 acres of ground, 65,528,000 cubic feet, being equal to $2\frac{4}{10}$ inches of rain. The rain at Crowden during this period appears to have been $2\frac{1}{10}$. To allow for the water which still remained to flow off the ground before the streams would regain their usual volume, we must add $\frac{3}{10}$ of an inch, (after allowing for the natural flow,) making the total quantity of rain which fell in 24 hours, as measured by the Woodhead Reservoir, $2\frac{7}{10}$ inches.

The rain which was discharged at Rhodes Wood, or impounded in that reservoir and Torside in the same time, exclusive of what was received from Woodhead, amounted to about 66,000,000 cubic feet of water from 7,900 acres, being, as nearly as may be, the same quantity per acre as that received at Woodhead. The calculations may, therefore, be taken to show accurately the quantity of water which flowed down the river during this extraordinary rain; showing also, that the average rain over the district, taking the whole period, must have been 9 or 10 per cent. greater than the quantity received by the Crowden Hall rain gauge.

The rain in the district from the commencement of the year to the 9th of February, as indicated by the several rain gauges, is as follows:—

	January.	February, to 9th.
At Crowden Hall........................	5 inches.	$6\frac{1}{2}$ inches.
" Butterley Moss	$5\frac{1}{10}$ "	$6\frac{4}{10}$ "
	$= 11\frac{1}{2}$ inches.	
" Black Clough................................	$10\frac{4}{10}$ "	
" Brushes	$8\frac{1}{10}$ to 8th Feb.	
" Windyate Edge..............................	$8\frac{5}{10}$ to 8th Feb.	

The following table will exhibit the daily quantities during the first nine days of February:—

	Inches.
Sunday, 1st..	0.5
Monday, 2nd..	0.4
Tuesday, 3rd..	0.5
Wednesday, 4th..	1.1
Thursday, 5th..	1.2
Friday, 6th..	0.8
Saturday, 7th..	0.2
Sunday, 8th *	1.3
Monday, 9th †	0.5
	6.5

On the night of Thursday, the 5th, between 4 p.m. and 8 a.m. of the 6th, there fell 0.7 of an inch of rain.

The quantity of water which flowed from the whole collecting ground of the waterworks, about 18,900 acres in extent, between the 1st of January and the 9th of February, exceeded 800,000,000 cubic feet; being nearly 200,000,000 cubic feet more than sufficient to fill all the waterworks reservoirs had they been empty on new year's day, although

* This was between 4 p.m. on Saturday and 4 p.m. on Sunday.

† This was from 4 p.m. on Sunday to 12 at noon on Monday.

their capacity is equal to 32,400 cubic feet for every acre of collecting ground.

No damage of any consequence was sustained by any portion of the works from the effect of the floods. Their efficiency was well tested and satisfactorily proved; but the heavy rain penetrating into some ancient land slips on the north side of the valley near the Rhodes Wood embankment, but above its level, set a mass of about 40 acres in extent in motion, which disturbed a quantity of masonry and otherwise deranged the scheme at the spot at which it occurred. The security of the reservoir is not affected; but it will be a work of time and skill to arrest or obviate the effects of this sliding mass.

VIII.—*On the Identity of Light, Heat, Electricity, Magnetism, and Gravitation.*

By J. Goodman, M.D., M.R.C.S.

[*Read March 8th*, 1852.]

In my experimental researches into the identity of these forces, I have long sought a great desideratum in Science, viz., an instrument which would give intimation of the progress and transition of caloric along the molecules of matter, or the interior construction of bodies, and I believe that object has been attained in the following experiments.

From the difference of temperature of bodies,—the facility with which we can increase the temperature of a cold body by the apposition of one already heated, and of cooling the latter also by the same contact,—and from a knowledge of the laws of transmission, diffusion, radiation, ignition, coction, fusion, and volatilization, by this force;—I cannot, in spite of all modern theories upon the subject, and the teaching of the Schools, draw any other conclusion than that this force *is a bonâ fide imponderable existence*, possessing the ordinary qualities of *matter—locality, extension, impenetrability, resistance, attraction, motion;* and, as I believe is shewn in the following experiments, *momentum* also—a property hitherto applied alone to ponderable matter.

That heat possesses the three former properties is not objected to by philosophers, inasmuch as it is not contended *that it enters into the substance of the atoms or elementary particles of matter*, and occupies with matter the same space at the same time, but simply is described as filling the interstices between these elementary particles. It is also as capable of transmission from one substance to another, as water when poured from vessel to vessel. It is to a certain extent capable of accumulation and *retention*, without renewal, like other fluids in nature; we find that the retention of these latter is of very short duration if left to evaporate, uncovered and unprotected, or in contact with leaky or porous substances.

There is therefore reasonable ground for concluding, that, as every known substance in nature is more or less porous to the calorific fluid, if caloric could be as effectually surrounded by substances incapable of its transmission as the liquids in daily use can be, we should be able to preserve it at any degree of intensity, and that without addition, for any protracted period.

But it is manifest that whatever may be the teaching of the Schools with regard to the nature of caloric—they all practically denominate it not as a mere mode of action or the result of motion among the particles of matter—but as a *bonâ fide* and genuine substance, and as endowed with all the powers and qualities usually attributed to real material existences.

The facts that appear to me especially unanswerable, bearing against modern theory are, that if one were to admit for the sake of argument that caloric is generated by friction, why does not the effect cease when the cause is discontinued?—why does it not cease to exist when friction ceases?—or else, why is not caloric daily and hourly accumulating? How is it that when by such heat generated we have kindled a fire, which might also be admitted to depend for its development on motion of a chemical nature occurring among its own particles,—how is it that by this same fire, once produced, we can communicate a certain degree of redness or white heat to a piece of iron or other substance, without producing any motion among its particles, and with this heated metal we can communicate warmth to the air, ignite a second fire, or boil water, which shall absorb just the exact amount of heat lost by the heated iron, and shall ultimately be able to retain this communicated caloric for a considerable period?

I think that heat is shewn, by these and other facts, to have an independent existence, so far as our present ideas of entity and non-entity extend.

Again, if caloric were admitted to be the mere creation of matter, how is it that the other imponderable forces, which are by many philosophers admitted as convertible into caloric, and *vice versâ*, are not by them also assigned to the same origin and the same mode of existence?

It has already been shewn by the labours of Dr. Wollaston, Dr. Faraday, and the author of this paper, that the ordinary electric and voltaic forces are identical; and many years ago the analogy of aërial electricity, or lightning, was sufficiently demonstrated by the experiments of Dr. Franklin.

The reciprocal influence and mutual dependence of these forces along with magnetism, and the obedience of electricity to some of the laws of magnetism, and *vice versâ*, as well as the analogy of the phenomena manifested by all these forces, evince their identity. In illustration of the identity of electricity with magnetism, I read a paper before the British Association in 1842, in which it was shewn that a plate of glass maintained in a constant polar condition by the simple current from the ordinary electrical machine, sustained the weight of 5 oz. and 20 grs.; shewing that frictional electricity itself, when placed in a condition resembling magnetism—or rather electro-magnetism—will produce with them an equivalent effect proportionate to its inferior quantity and powers.

With regard to the identity of light and heat—forces which I hold to be so far identical as to be in their common acceptation simply the *essential qualities* of the one subtile force under investigation—I refer to the experimental labours of M. Melloni and Professor Draper.

We have, therefore, deficient only one link in the chain of identity among all these imponderable forces, and that link is the identity of the force light or heat, with electricity. I have already shewn that there are many points of analogy between voltaic electricity and the calorific force. Each of these forces is found occupying the interior or so-called interstitial space of the elements of bodies, they are the admitted agents which operate upon the elementary particles or atoms of matter,* and are possessed of essential qualities common to both, which are exhibited in all their luminiferous and calorific phenomena.

It is this link which I believe is discovered and supplied by the following experiments. The account of these is copied almost verbatim from my experimental note book, from November, 1850.

My delicate galvanometer, which has been employed in all my previous experiments, is composed of a helix of forty-six turns of covered copper wire $\frac{1}{25}$ of an inch in diameter, and a single needle suspended by about 16 or 18 inches of silk fibre—the indicator is a slender wooden fibre, and moves over a card dial, which shades the upper surface of the helix.

I found on placing it in a window having a southern aspect, that it was impossible in the day time to obtain at all times certain indications. At other times I observed *a constant vibratory motion* to such an extent that I was unable to proceed with my experiments. Desiring to discover the reason of such action, on the 14th of November last, the needle at that time vibrating to a considerable extent, I *intercepted* the progress of the *sun's rays*, which were *shining upon the southern extremity of the galvanometer*, by a book or any thing near at hand, and *the needle became stationary*. On

* This is not the case with any of the other forces. See Report of British Association for 1842.

removing the book, deflection again commenced, and the needle continued to perform vibrations of about 10° so long as the sun's rays continued upon it.

At 12, (noon,) placed the book again so as to intercept the solar rays, the needle still vibrating; this gradually diminished until it became perfectly stationary, and remained so up to 12h. 7½m. Removed the book, and in half a minute the galvanometer vibrated to 5°, and became stationary at 2½°. Replaced the book, and the needle returned to 1½°. The sun had now so changed his position that the other or north extremity of the helix had also become illuminated. On placing a small book to shade the latter from the sun's rays, the galvanometer needle slowly travelled as far as 0½°, then receded to 5° below zero, and kept up a continuous vibration from this point towards zero,—the instrument having been previously adjusted. On intercepting the sun's rays the galvanometer declined to zero, and there remained perfectly stationary for five minutes.

At 12h. 20m., the galvanometer being still stationary, I removed the book, and in one minute it had progressed to 2½°. All action now ceased, and the needle became stationary at this point.

December 6th, 1850.—Observed the galvanometer at 2½° at 12, (noon.) Adjusted it; but observed that whenever the sun began to shine brightly, it became several degrees deflected. At 1h. 20m., on paying more particular attention to this circumstance, I found that by interposing a piece of paper or other screen between the instrument and the solar rays, the deviation was corrected.

I found that by rectifying the instrument in the sun's rays and then interposing a screen, the needle deviated to *the left hand* 2½°,—and on removing the screen, it speedily returned to its original station. This experiment I repeated about every half minute for a dozen times, and the same results invariably ensued. The needle always answered to the sun's rays when unobstructed, and at all times to the same distance. (See later experiments.)

3h. p.m.—The needle has now deflected 4½° to 5° in the sun's rays. On interposing the screen, it returns 2°, and on removing it, vibrates again to 5°; and this action is maintained as long as I please, by the mere interposition or removal of the screen.

Is this Thermo-Electric Action?

In order to see whether the effect was due to any thermo-electric influence, I *retained* the south end of the helix in the mercury cup, exposed to the solar rays, whilst the screen was interposed; but this in nowise altered the results. I then *removed the mercury cups* altogether; but the action of the needle was just as before. The sun is now beginning to illuminate the north end of the helix as much as the opposite; the action becomes weaker, and in a short time 1° is the whole effect produced.

December 12th.—The galvanometer has now been stationary two nights and one day. No sunshine yesterday, and no deflection.

On the emerging of the sun from behind a cloud this morning at 11, the needle deflected gradually to 3° towards *the right hand.* On interposing a screen to obstruct the rays, it declined speedily to 2°.

When the screen was removed, the sun shining brightly, the galvanometer indicated 4°. Interposed the screen, galvanometer, 0°. Removed the obstruction, and in one minute galvanometer indicated 2½°. The power of the solar rays is indicated with as great precision as with a thermometer; a cloud intervening, 2° is indicated.

December 13th.—A cloudy day. 11h. 55m., the sun has just emerged, and the galvanometer moves 2¾° *to the right.* The sun is again obstructed, and the indicator stands at zero. 1h. 55m., some cloudy films intervening, the galvanometer indicates 4°. More clouds intervene directly, and it returns to zero again.

December 15th., at 10 a.m. The sun is now in a direct line with the helix. The indicator 5° *to the right hand.* Placed a screen between the sun and the instrument, and in a few seconds it has returned to zero.

It may be noticed that in all these experiments the sun's rays had to penetrate the glass of the window as well as the glass shade of the instrument.

I now used a large lens to condense the rays upon some of the wires at the south end of the helix, but found that this condensation deprived the rays of their influence upon the galvanometer.

That the results were not due to thermo-electric action is manifest. In these experiments there was no electric *circuit* formed. There was no wire of communication between the two mercury cups forming the terminations of the helix, and therefore, upon all commonly admitted principles, there could be neither ordinary voltaic, or thermo-electric phenomena manifested, for the latter are never seen unless the electrical circuit is complete.

I *now completed the circuit* by a connecting copper wire, one extremity of which was introduced into each mercury cup. When the sun became partially unclouded, the galvanometer indicated 3°. I removed the connexion, and completed it again and again several times, but without any sensible change.

It is now 4°. I break the circuit, but no effect ensues; still 4°. The sun shining brightly, at 10h. 45m., 5°. The wire of connexion is removed, and after one minute the galvanometer still indicates 5°. Clouds intervene, and the needle declines. The introduction of the connecting wire produces no alteration during the decline of the needle.

Shortly, although clouds of a fine texture intervene, the galvanometer marks 5°, with no wire of connexion between the mercury cups. By completing the circuit, no change; in two minutes the indicator marks 4°. Removed the connecting wire, and the galvanometer remains as before, at 4°.

I now interposed a screen. In ½ min. the needle receded to 0½°; in 1½ m., quite to zero. Removed the screen at 11.20 a.m., and in 1 m. galvanometer 2½°; in 1½ m., 4½°; in 1¾ m., 5°; in 2 m., the *sun now unclouded,* 6°. Circuit incomplete.

Removed the mercury cup into which the south wire was inserted—the only one illuminated by the solar rays. The sun being quite unclouded, the needle indicated 10°. I again interposed the screen, and the needle returned to 2½°. Fearing lest the galvanometer had been altered, as the indication was so high, I removed zero to where the needle became stationary at 2½°; and on taking away the screen, in 1 m. the needle indicated 7½°, and afterwards 8°. At 11h. 35m., the needle deflected to 9°. The mercurialized end of the galvanometer wire was now enclosed in paper, to ensure that there should be no supposed thermo-electric action by heating copper in communication with mercury; but the galvanometer remained just as before.

There was no alteration in the results obtained by plunging a wire, in connection with the north end or terminal of the galvanometer, into cold water.

The sun's rays are beginning to fall upon and illuminate *the north extremity* of the helix, and the needle gradually declines.

January 3rd, 1851.—All the following deflections were to *the right hand*:—

a.m., 11h. 30m. Sun somewhat clouded, galvanometer 2°.
" 11 . 45. " brighter, " 2½°.
" 11 . 50. " still brighter, " 6°.
p.m., 4 . 55. " bright; the galvanometer now indicates 8°.

Interposed a screen, and the galvanometer declined to zero.

p.m., 2 . 0	Sun clouded,	galvanometer	2½°.
" "	" more clouded,	"	2°.
" "	" still more clouded,	"	1°.

8 . 0 in the evening. Galvanometer had returned to 0°, as usual.

January 6th.—One half the extremity of the helix shaded by a pillar.

a.m., 10h. 0m.	Galvanometer deflected to	3°.
" 11 . 50.	Sun clear, unshaded, galvanometer	7½°.
" "	Interposed a screen, and in ½ min. "	5°.
" "	Removed " " "	7½°.
	Repeated, with like results, several times.	
" 12 . 0.	Sun unclouded, galvanometer	9°.
p.m., 12 . 1.	Galvanometer 10°; 1 min. more	11°.
" 12 . 3.	Window and apparatus very clean,	12°.
" 12 . 5.	Galvanometer	15°.
" 12 . 7½.	Ditto	15°.

The instrument had been cleaned and might not have been correctly adjusted—and probably the last stated degrees are overrated. The wires at the south extremity of the helix, which were originally green, were now inked, so as to produce a greater facility for the absorption of the rays. The galvanometer ultimately settled in the evening at 5°, which would reduce the stated indication of the galvanometer from 15° to 10°, as before.

January 18th; a.m., 11h. 0m. Sun clouded, galvanometer .... 7½°.

A little more obscured, 5°; sun brighter, but not free from clouds .... 7½°.

Now 8°; sun more obscured, galvanometer declined to .... 4°.

In ½ a min. 5°; 1 min., sun yet clouded............ 6°.

The motions of the galvanometer appear much *more rapid* since the blackening of the extremity of the helix.

p.m., 12h. 45m. The sun is now out again, the galvanometer deflects to 4°, then .... 5°.
The rays obstructed by a cloud, it declines to ... 1°.
The sun becoming brighter, 6°; now............... 7°.
Obscured still by thin clouds, and no prospect of being clearer.. 7°.

N.B. Up to this period the deflections had been from the 12th December *all to the right hand.*

The Vibratory Period.

Effects of Shade—Deflection changed.

January 22nd, 1851, a.m., 9h. 45m.—Half the helix shaded by a pillar, galvanometer 4° *to the right hand.* Two-thirds shaded, galvanometer 2½°. The shade still encroaching, the galvanometer gradually declines. Now 3 wires only unshaded, galvanometer 2°, and at length zero.

11h. 45m. The *sun is now brightly shining* upon the whole extremity of the helix and all along the lower bundle of wires, and the *galvanometer remains at zero.*

A piece of sheet copper was now interposed as a screen to shade the lower bundle of wires of the helix, and permit the rays to illuminate only its extremity—galvanometer deflected to 7½°.

It will be observed that it was the 22nd of January, at mid-day, and the sun had ascended a considerable altitude above the horizon. The influence hitherto exerted on the galvanometer appeared destroyed. *Sometimes it would diverge in one direction, and sometimes in the opposite. Vibratory movements began again to make their appearance* as they had done on the 14th of November, 1850; at which period, and for some time afterwards, the deflections of the needle were towards the left hand. *By and bye, the galvanometer* *settles; but its deflection is reversed, and takes place to the left*, $2\frac{1}{2}°$.

On interposing a screen, it returns to zero,—and on removing the obstruction, it is deflected again to *the left hand*, $2\frac{1}{2}°$. By alternately intercepting the rays, and then removing the screen, a continuous vibration is maintained in the new direction of $2\frac{1}{2}°$ to 3°.

January 23rd, 11h. 30m.—Sun out, galvanometer deflects to the right hand .... $7\frac{1}{2}°$.

11h. 40m. Very bright, galvanometer deflects to the right hand .... 10°.

11h. 53m. Sun clouded, galvanometer declines 5°.

p.m., 12h. 5m. Sun unclouded, galvanometer deflects *to the right* .... 9°.

Again—

" 2 0. Sun bright, galvanometer *deflects to the left* .... 2°.

" 2 5. Ditto, ditto ditto......... $2\frac{1}{2}°$.

" 2 45. Sun obscured, ditto......... 0°.

January 27th, 9 . 30.—Sun unclouded, galvanometer 5° to the *right hand.*

9h. 35m. Sun unclouded, galvanometer 6° to the right hand.

9h. 55m. The end of the helix is now covered entirely by the shade of an iron pillar. The left side and surface of the lower bundle are illuminated by the sun's rays, and the needle has declined to 1°.

10h. 0m., a.m. The rays now illuminate one-third of the end of the helix, and the galvanometer marks $2\frac{1}{2}°$ *to right.* The left side and lower bundle of the helix was now shaded by a screen, and the needle speedily marked 6° to the right, the helix being only half illuminated at its extremity.

10h. 45m. The sun is now at a considerable altitude above the horizon, but the glass shade of the instrument is covered with condensed vapour internally, and prevents the action of the rays; galvanometer at zero.

2h. 15m. The needle is now deflected *towards the left* 1°. The whole of the helix (save the extremity) was now shaded from the rays, and the immediate result was 4° *to the left*. The shade was removed, and the needle declined to 2½°. Replaced the shade, and the result was 3½° to the left.

2h. 35m. Needle 1°. Shaded the whole of the helix except the south illuminated end, and the result *to the left hand* was 3°.

January 31st.—The greater part of the helix being covered by the shade of the window frame, *the needle began to vibrate*, and continued its vibrations for some time. Shortly afterwards two-thirds of the extremity of the helix being illuminated, the needle deflected 4° *to left*.

11h. 35m. Sun clouded, galvanometer 3° *to left*. Helix shaded, declined to 0°.

2h. 20m. Shaded the helix, 0°. On removing shade, 3° *to the left hand*.

February 14th, 1851.—Sun much clouded.

9h. 40m. No deflexion; afterwards shaded the lower half of the extremity of the helix, result, 1° *towards the right*. A cloud intervened, and it declined to 0°.

11h. 20m. Galvanometer marks 2½° *to left*. Shaded upper half, no deflexion; shaded whole helix, and no deflexion; shaded lower half, and galvanometer indicated 5°. This was repeated several times, with similar results.

Covered the whole length of the silk line supporting the needle with a paper shade, lest there might be any results from the action of the rays upon it. The shade was frequently removed and replaced during deflections of the needle, but no influence appeared to result from these changes.

12h. 50m. Galvanometer marks 2½° *to the left hand*. The sun becomes bright, and the deflection that ensued was

6° *to left.* Covering the lower half of the helix now appears to diminish the amount of deflection.

February 26th, 10h. 55m.—The needle marks 3° to 4° *to the left hand,* and by interposing the screen the indicator returns to zero.

March 3rd, 1.40 p.m.—Sun rather clouded; the galvanometer indicates 6° *to the left hand.* Clouds intervene, and in a few moments the needle declines to 2½°.

1h. 45m. The sun again emerged, and the galvanometer deflected to 6° *to the left,* and continued to move in one direction or the other just in proportion to the brightness or obscured condition of the solar rays.

March 4th, 10h. 54m.—The sun being very bright, the galvanometer was observed to deviate 10° *to the left hand.*

In order to see if any similar effect could be produced by ordinary heat, I employed a spirit lamp, held near the extremity of the helix, but no deflection ensued.

Afterwards I held a pile of red hot burning embers at the north extremity of the helix, resting upon a piece of sheet copper, and a deviation of the needle to the left hand ensued, equal to about ½°. The embers were then removed to the opposite extremity, when, as the north end became cooler, the needle passed zero and deflected about ½° to the right. This was performed several times with similar results. Afterwards the mercury cups were removed, but the needle deflected under the influence of the embers just as before.

The shade of the apparatus was heated very considerably by this proceeding, and much more than by the solar rays for the production of a deflection of 10°.

June 27th, 1851.—I have since discovered that not only is the deflection of the needle produced by the solar rays falling upon the southern extremity of the helix, and obstructed by the illumination at the same time of the northern extremity, but that their projection upon the upper surface of the helix produces an action completely antagonistic to that of the sun's action upon its southern extremity. Thus on June 27th, 1850, the opening in the dial card having been enlarged, the needle deflected to 10°; exposed the upper bundles of the helix to the sun's rays, the needle returned to 7½°, and vibrated continually at this point. Shaded the dial opening, and the needle deflected to 10°, and afterwards 11°. This experiment was performed several times and attended with similar results. By shading the extremity of the helix and exposing its upper surface only, needle reversed 3° *to the right hand.*

The powers of reflected light were tried by reflecting the solar rays upon various portions of the helix, and this in a variety of directions, but without any change occurring in the position of the needle.

I also verified the experiments of 1850-51, by similar experiments in 1851-52, at like periods of the year, but invariably with the same kind of deflection, and in the same direction corresponding with the altitude of the sun above the horizon.

Thus September 10th, 1851, 1h. 30m., deflection *to the left hand,* 3°.

At 3h. 45m. The northern extremity of the helix was alone illuminated, but no deflection of the needle could be obtained. The same results occurred also in October, and November—deflection 5° to the left.

THE VIBRATORY PERIOD, 1852.

1852, January 23rd, 12½ p.m.—*Deflection to the right hand,* as in the previous year at this date, and the needle returned to zero on obstructing the rays.

January 30th, 12 noon.—Galvanometer deflects to *the right hand,* the sun becomes obscured, and the needle returns.

February 12th, 10h. 40m.—Needle deflects 3° to the *left* *hand;* shaded by a pillar, goes back to zero. At 11 a.m., needle stationary, yet the sun very powerful. At 11h. 10m., the needle deflects 2° to the *right hand;* at 3h. 12m., it now vibrates again towards the *left hand;* shaded the helix, zero; removed the shade, deflection 1° *to the right hand;* it now vibrates 2° *to the left*, and continues vibrating.

11h. 20m. Begins by deflection *to the right*, and then in a few seconds to the *left*, then vibrates or remains stationary.

12h. 5m. The needle is now 4½° to the right; shaded, it returns; 12h. 10m., deflection 7½° to the right hand.

It is thus seen that the instrument, which is ordinarily employed for the indication of a voltaic current, and has been shown also to manifest the transition of ordinary electricity and lightning, is likewise truly affected by the solar beams.

That the effects upon the galvanometer are induced by solar agency, is clearly manifested in the greater part of the above experiments by the remarkable coincidence which is observable between the degrees indicated by the galvanometer and the brilliancy of the solar beams, as well as by the changes observed by the interposition or removal of an artificial screen. (See Experiments, Jan. 3rd, 6th, and 7th.)

That the effects are not the results of thermo-electric action, is evident, inasmuch as,—

1. There has never been discovered any thermo-electric phenomenon emanating from the action of heat upon any *simple combinations of copper wire alone.*

2. That there was no thermo-electric influence observable from the action of heat *upon copper in contact with the mercury* in the mercury cup, nor upon the mercurialised extremity of the wire, was seen on the 6th December last; for after the removal of the mercury cup and shading the wire from the sun's rays, the same results were still equally observable. (See Experiment, Dec. 6.)

3. There is no hitherto known electric, thermo-electric, or voltaic action of this kind noticed in science *without the*

formation of a complete circuit; and yet there was no circuit formed in most of these experiments, nor did the completion of the circuit at all augment, decrease, or influence any of the results. (See Experiments, Dec. 15.)

That the effects are due to the influence of the solar rays upon the *southern extremity of the helix*, was manifested on several occasions by the same and frequently an increased action upon the needle ensuing by the shading of the other parts of the helix. (See Experiments, Jan. 22nd and 27th.)

The unexpected change which took place in the direction of the needle on the 22nd of January, at 12 noon, and which appears to have continued from that period to the present at all times after a given hour,—being *to the right hand with the early and winter sun, and to the left hand when the latter has advanced far above the horizon,*—evinces that the influence of the rays in inducing the direction of the current in the helix at these two periods is antagonistic; this is also displayed by *the stationary or vibrating condition of the needle at the interval between these two periods.* This vibratory motion is also observed at all times when two antagonistic currents are induced. (See Experiments, Jan. 12th, 23rd, and 27th.)

The vertical action of the rays upon the helix in the production of current, and its electro-magnetic effects upon the needle, appear to depend upon the intensity and momentum of the solar rays, which probably enter into and traverse the wires in that direction which most nearly corresponds to the direction of the rays; the deflection of the needle in each instance corresponding, according to known laws, to the direction of the current thus induced.

That the action is *augmented in proportion to the number of coils* of the helix acted upon, was evidenced in several experiments, and particularly in those of the 22nd of January.

Thus it appears that each ray as it falls upon a coil of the helix traverses it with a given degree of momentum, and that when the current thus produced arrives at the continuous portion of the coil where it becomes subject to the action of a second ray, its momentum is increased, and probably the quantity of moving force doubled; and this increase of momentum and force is after the same manner augmented in each succeeding coil by every fresh incidental ray.

The result of these experiments evince to my mind more than ever the *unity of force.* On every hand experimental evidence appears to justify the conclusion that there is *one* universal force in Nature, which is modified by the accidental and varied conditions to which it is subject, but *that its essential nature and characteristics are at all times the same, and evince in every modification constantly the same unchangeable qualities,* which are discoverable by man under the denomination of *sensations,* as well as luminous and calorific properties.

I believe that these experiments indicate, and indeed prove the identity of caloric and voltaic force, and that now the last required link for the completion of the entire chain of identity of these imponderable forces is obtained.

IX.—*On the economical production of Mechanical Effect from Chemical Forces.*

By J. P. Joule, F.R.S., &c.

[*Read April 6th,* 1852.]

Perhaps the most important applications of dynamical theory are those which refer to the production of motive power from chemical and other actions. To point out the rules for constructing an engine which shall approach perfection as nearly as possible, and to determine the quantity of work which ought to be evolved by a perfect engine of any given class, are objects of the greatest consequence in the present state of society, and which have in fact been to a great extent already accomplished by the labours of those who have taken a correct view of the nature of heat. I intend on the present occasion to submit to the Society some of the laws which have been recently arrived at by Professor Thomson and myself, and to offer some hints as to the means of carrying out into practice the deductions of theory.

Engines which derive their power from the operation of chemical forces may be divided into three classes. The first class comprises those exquisite machines in which chemical forces operate by the mysterious intervention of life, whether in the animal or vegetable creation. The second class includes machines in which the chemical forces act through the intervention of electrical currents, as in the ordinary revolving electro-magnetic apparatus. The third comprises those engines in which the chemical forces act through the intervention of the heat they produce; these, which may be termed thermo-dynamic engines, include steam engines, air engines, &c.

The process whereby muscular effort is developed in the living machine is, as might be expected, involved in great obscurity. Professor Magnus has endeavoured to prove that the oxygen inspired by an animal does not immediately enter into combination with the blood, but is mechanically conveyed by it to the capillary vessels within the muscles, where it combines with certain substances, converting them into carbonic acid and water. The carbonic acid, instead of oxygen, is then absorbed by the blood, and is discharged therefrom when it reaches the lungs. Taking this view, we may admit with Liebig, that at each effort of an animal a portion of muscular fibre unites with oxygen, and that the whole force of combination is converted by some mysterious process into muscular power, without any waste in the form of heat. This conclusion, which is confirmed by the experiments related in a joint memoir by Dr. Scoresby and myself, shows that the animal frame, though destined to fulfil so many other ends, is as an engine more perfect in the economy of *vis viva* than any human contrivance.

The electro-magnetic engine presents some features of similarity to the living machine, and approaches it in the large proportion of the chemical action which it is able to evolve as mechanical force. If we denote the intensity of current electricity when the engine is at rest by a, and the intensity of current when the engine is at work by b, the proportion of chemical force converted into motive force will be $\frac{a-b}{a}$, and the quantity wasted in the form of heat will be $\frac{b}{a}$. Now from my own experiments, I find that each grain of zinc consumed in a Daniell's battery will raise the temperature of a lb. of water $0^\circ{\cdot}1886$; and that the heat which can increase the temperature of a pound of water by one degree, is equal to the mechanical force which is able to raise a weight of 772 lbs. to the height of one foot, or according to the expression generally used, to 772 foot-pounds. Therefore the work developed by a grain of zinc consumed in a Daniell's battery is given by the equation,

$$W = \frac{145{\cdot}6\,(a-b)}{a}$$

We now come to the third class of engines, or those in which the chemical forces act through the intervention of heat. In the most important of these the immediate agent is the elasticity of vapour or permanently elastic fluids. In a very valuable paper on the dynamical theory of heat, Professor Wm. Thomson has demonstrated that if the heat evolved by compressing an elastic fluid be equivalent to the force absorbed in the compression, the proportion of heat converted into mechanical effect by any perfect thermo-dynamic engine will be equal to the range of temperature divided by the highest temperature from the absolute zero of temperature. Therefore, if in a perfect steam engine a be the temperature of the boiler from the absolute zero, and b be the absolute temperature of the condenser, the fraction of the entire quantity of heat communicated to the boiler which will be converted into mechanical force, will be represented by $\frac{a-b}{a}$, which is analogous to the fraction representing the proportion of chemical force converted into mechanical effect in the electro-magnetic engine.* The entreme simplicity of this very important deduction which Professor Thomson has drawn from the dynamical theory of heat, is of itself a strong argument in favor of that theory, even if it were not already established by decisive experiments.

* Referring to this analogy, Professor Thompson writes as follows :—" I am inclined to think that an electric current circnlating in a closed conductor *is heat*, and becomes capable of producing thermometric effects by being frittered down into smaller local circuits or 'molecular vortices.'"—Letter to the Author, dated March 31st, 1852.

Now, estimating the heat generated by the combustion of a grain of coal at 1°·634 per lb. of water, its absolute mechanical value will amount to 1261·45 foot-pounds; hence, according to Professor Thomson's formula, the work performed by any perfect thermo-dynamic engine will, for each grain of coal consumed, be represented by the equation,

$$W = \frac{1261 \cdot 45\,(a - b)}{a}$$

which applies, as before intimated, not only to air engines, but also to those steam engines in which the principle of expansion is carried to the utmost extent, providing always that no waste of power is allowed to take place in friction, and that the entire heat of combustion of the coal is conveyed to the boiler or air receiver.

Professor Thomson was the first to point out the great advantages to be anticipated from the air-engine, in consequence of the extensive range of temperature which it may be made to possess; and in a paper communicated to the Royal Society soon afterwards, I described a very simple engine which fulfils the criterion of perfection according to Professor Thomson's formula. This engine consists of three parts, viz., a condensing air pump, a receiver, and an expansion cylinder; the pump forces atmospheric air into the receiver, in the receiver its elasticity is increased by the application of heat, and then the air enters the expansion cylinder, of which the volume is to that of the pump as the absolute temperature of the air in the receiver is to that of the air entering it. The cylinder is furnished with expansion gear to shut off the air, when the same quantity has been expelled from the receiver as was forced into it by one stroke of the pump. By this disposition the air is expelled from the expansion cylinder at the atmospheric pressure, and at the absolute temperature corresponding with b in Professor Thomson's formula.

As an example of the above kind of air-engine, I will take one working in atmospheric air of 15 lbs. pressure on the square inch and 50° Fahr. I will suppose that the expansive action in the cylinder is to exist through three-fourths of its length. Then as the action of the compressing pump is the reverse of that of the cylinder, the piston of the former must traverse three-fourths of its length before the air is sufficiently compressed to enter the receiver by its own pressure. The temperature of the air entering the receiver, determined by Poisson's equation $\frac{t'}{t} = \left(\frac{V}{V'}\right)^{k-1}$, will be 439°·59 Fahr., and its pressure will be 105·92 lbs. on the square inch. Supposing now that the volume of the cylinder is to that of the pump as 4 to 3, the density of the air in the receiver to that forced into it by the pump must be as 3 to 4 in order to keep the quantity of air in the receiver constant. The temperature of the air in the receiver will also require to be kept at 739°·12 Fahr. in order to maintain the pressure of 105·92 lbs. on the square inch. The air entering the cylinder at the above pressure and temperature will escape from it at the end of the stroke at the atmospheric pressure, and at the temperature 219⅔°.

It will be remarked that there are two ranges of temperatures in the engine I have described, viz., that of the pump and that of the cylinder. Owing, however, to the exact proportion which subsists between the two, the same result is arrived at by the application of Professor Thomson's formula to either of them. Taking, therefore, the range of the cylinder, and converting the temperatures of the air entering and discharged from the cylinder into the absolute temperatures from the real zero by adding to them 459°, we obtain for the work evolved by the consumption of a grain of coal,

$$W = \frac{1261{\cdot}45\,(1198{\cdot}12 - 678{\cdot}66)}{1198{\cdot}12} = 546{\cdot}92 \text{ foot-pounds.}$$

In order to compare the foregoing result with the duty of a steam-engine approaching perfection as nearly as possible, I will admit that steam may be safely worked at a pressure of 14 atmospheres. The temperature of the boiler corresponding to that pressure will, according to the experiments of the French Academicians, be 387° Fahr. The temperature of the condenser might be kept at 80°. Reducing the above to temperatures reckoned from the absolute zero, we obtain for the work evolved by the combustion of each grain of coal,

$$W = \frac{1261{\cdot}45\,(846 - 539)}{846} = 457{\cdot}76 \text{ foot-pounds.}$$

It would therefore appear, even in the extreme case which I have adduced, that the performance of the steam-engine is considerably inferior to that of the air engine. The superiority of the latter would have been still more evident had I also taken an extreme case as an illustration of its economy. It must, moreover, be remarked that the heated air escaping from the engine at a temperature so high as 219¾° might be made available in a variety of ways to increase still more the quantity of work evolved. A part of this heated air might also be employed in the furnaces instead of cold atmospheric air.

We may also hope eventually to realize the great advantage which would be secured to the air engine by causing the air, in its passage from the pump to the cylinder, to come into contact with the fuel by the combustion of which its elasticity is to be increased. It appears to me that the air might pass through a number of air-tight chambers, each containing ignited fuel, and that whenever any one of the chambers required replenishing, its connexion with the engine might be cut off by means of proper valves, until by removing an air-tight lid or door the chamber could be filled again with fuel. By means of suitable valves, it would be easy to regulate the quantity of air passing through each chamber so as to keep its temperature uniform; and by a separate pipe, furnished also with valves, by which the air could be carried from the pump to the upper part of the chambers without traversing the fuel, the engine man would be enabled to keep the temperatures of the chambers, as well as the velocity of the engine, under proper control.

X.—*On some Trails and Holes found in rocks of the Carboniferous Strata, with remarks on the Microconchus carbonarius.*

By E. W. Binney.

[*Read April 6th*, 1852.]

Notwithstanding the great attention that has of late years been bestowed by geologists in investigating the state and condition of our globe at the time of the formation of the carboniferous strata, much yet remains to be done. Every fact connected with the subject, however trivial it may at first sight appear, deserves to be recorded. The collectors of fossil shells and plants were for a long time considered by the practical collier as mere curiosity hunters, whose labours would do little to guide him in determining the regular succession of strata or the origin of the coal itself. But the time has arrived when fossil organic remains have their use in the mind of the intelligent miner as well as of the distinguished palæontologist, by affording valuable assistance in identifying beds at different places when the deposits themselves are so changed in appearance as not to be recognized. Doubtless they require to be used in conjunction with other facts, such as the mechanical condition of rocks, and various circumstances; but still, their value is now so generally allowed, that it will not require any further argument from me for its support.

In this communication it is my object to direct attention to the markings which appear upon the surfaces of certain rocks belonging to the carboniferous strata. The subject has not particularly engaged the minds of English geologists; indeed, so far as I am aware, little has yet been done in it with the exception of the investigation of the origin of ripple marks upon flagstones. This has excited considerable interest, and it is now pretty well determined that these appearances, although more frequently indicating the former existence of sea beaches and beds formed in shallow water, are by no means to be confined to those conditions, as they have been found in the present seas under several hundred feet of water. Your attention will chiefly be requested to the trails of the former inhabitants of shells and worms, as well as the burrowings of the latter, made on and in the rocks, when they were in the state of soft sand or mud; but some observations will also be made upon those common annelids which have long passed for molluscs, and were known by the name of *microconchus carbonarius*.

The above-named humble memorials of the *fauna* of the carboniferous epoch must at present suffice for our consideration. There is little doubt, however, but that reptilian remains will be found amongst the coal measures in England, like those of Germany and the United States of America. The tracks and trails as yet met with in these rocks give no indication of having been made by reptiles, like those found in the new red sandstone of Weston, Cheshire, and other places, as well as the old red sandstone of Scotland. In my cabinet is a vertebra from the roof of the Riley Coal at Captain Fold, near Heywood, which the most celebrated living comparative anatomists cannot distinguish from the caudal vertebra of an *ichthyosaurus*. As, however, no other bones were met with in that locality, doubts have been raised as to the authenticity of the specimen; but as to its having really been found in the place where it was represented to have come from, there is quite as much evidence as of three-fourths of the fossil remains which are labelled in cabinets.

Most of the trails and marks found upon the rocks of the carboniferous strata have evidently been made by at least two very different kinds of animals. Some of them have been excavated by annelids, whilst others have been made by inhabitants of univalve and bivalve shells. These trails are often so much alike as to render it difficult to decide as to which of the above-named animals it is that we must attribute their origin. In the Silurian System,* Sir Roderick Murchison has referred certain markings found upon the Cambrian rocks of Lampeter to *nereites*, *myrianites*, and *nemerites*. These fossils Professor Hall, from an examination of many specimens of similar fossils found in the United States of America, is more inclined to refer to gasteropodous molluscs and crustaceans analogous to *idotea*.† Without undertaking to determine which of the above learned authors is correct, I shall describe in this communication markings, some of which are the trails of the former inhabitants of shells, and others as equally certain to have been made by worms.

Mr. William Lee, of Sheffield, in a paper on Fossil Footprints of the Carboniferous System,‡ after describing several varieties of what he terms the tracks of reptiles, states,—"In May last, (1841,) I found upon the moors of Fullwood Head, five or six miles west of Sheffield, some beds of brown sandstone, covered with foot prints, and also with what appear to be the tracks of worms; (No. 4.) the surfaces are otherwise exceedingly smooth and even. The beds vary from two inches thick to one-sixteenth of an inch, and both the upper and lower surfaces are covered so abundantly with scales of mica, that it may frequently be scraped off with the fingers.

"The foot prints and worm tracks occur on both sides of the slabs, *the indentations being always on the upper surface, and the reliefs on the lower.*

* Silurian System, p. 699.

† Report of the American Association for the Advancement of Science held at Cambridge in 1849, p. 257.

‡ Vol. I. of the Proceedings of the Geological and Polytechnic Society of the West Riding of Yorkshire, p. 413.

"Upon one slab, I have without much difficulty deciphered nearly *forty* continuous impressions of the same track. The stride appears to be somewhat more than an inch, and behind the marks are frequently short furrows similar to those already described, where the feet have been drawn along the surface. No *marl* or *clay* is found in connexion with the stratum, the preserving agent in this instance being the interposed micaceous scales."

I have examined the quarry at Fullwood, above alluded to by Mr. Lee, and found specimens similar to those hereinafter described as occurring at Scout Mill in the lower flags. The Scout Mill and Fullwood Head quarries occupy the same geological position, and I have therefore little doubt but that the impressions on the surfaces of both flags have been made by the same kind of animal.

Having made these introductory remarks, it may be as well to give a section shewing the geological position of the several strata wherein the fossils occur. This section will be confined to the limestone shale and the lower division of the Lancashire coal field. A part of it has appeared in a paper by me, printed in the first volume of the Transactions of the Manchester Geological Society.*

SECTION OF THE LOWER DIVISION OF THE LANCASHIRE COAL FIELD.

	yds.	ft.	in.	
Coal, Lees, or Dogshaw Mine (the black Shale Coal of Sheffield.) ...	1	2	0	This coal is the last thick seam, and identical with the Lower Woodley Mine of Dukinfield, the Riley Mine of Oldham, the Arley Mine at Wigan, the Daubhill Mine near Bolton, and the Yew-Tree Mine of St. Helens. In Harwood it is very thin.

* In preparing this section, I have been much assisted by Mr. John Hall, of Nangreaves, and his brother, Mr. William Hall. The thicknesses of the different strata are only approximate, and were taken chiefly near Bury and in Rossendale. Many of the thin coal floors, all containing *stigmariæ*, are omitted.

	yds.	ft.	in.	
Floor, full of small Ironstone Nodules	1	2	0	
Black, heavy Stone, of a crystalline structure	1	0	0	
Blue Shale	6	1	6	
Light-coloured Rock	21	0	0	This rock is of a red colour at Harwood and Otterscoe Bridge, near Marple.
White earthy Shale	60	0	0	
Very black Shale	30	0	0	
Curled Stone, resembling impure Gannister	0	2	0	
Light Shale	10	0	0	
Grey flaggy Rock (Old Lawrence), Elland Flag in Yorkshire	6	1	6	It sometimes exceeds twenty yards in thickness; but it is always parted by layers of shale, three or four feet thick. It is worked at Kerridge near Bollington, Holy Fold in Romilly, Catlow near Colne, Bagslate near Rochdale, Harwood and Doffcocker near Bolton, Enfield near Accrington, Wrightington, Upholland, and Huyton.
Black stony Shale	30	0	0	
Black Iridescent Shale, containing Shells of the genera *avicula (pecten)*, *goniatites*, &c.	6	0	0	
Coal (Pyritous)	0	1	0	This coal is near eighteen inches thick in the neighbourhood of Bacup.
Black dirty Shale	12	0	0	
Grey lumpy Shale	3	1	6	
Brownish dirty Rock, full of black streaks	4	1	6	
Hard sharp Sandstone, (Tumbling Cob Rock,) well seen at Ending Common, near Whitworth	4	0	0	
Dark grey Shale, which swells much on exposure to the atmosphere	40	0	0	
Coal	0	0	8	
Grey Metals	3	0	0	

	yds.	ft.	in.	
White flaggy Rock, marked with red streaks and edges	4	1	6	
Dark Shale, containing Shells of the genera *avicula (pecten)*, *goniatites, &c.*	5	0	0	
Coal (Gannister), excellent for smithy purposes, and often called the "Rabbit" and "Mountain" mine, from the circumstances of its being generally worked by means of levels on the hill sides	0	1	8	The principal mine of Staleybridge, Waterhead, Rochdale, Bacup, Burnley, Blackburn, Habergham Eaves, Halliwell, Darwen, Chorley, Upholland, and Newburgh. It varies in thickness from five feet eight inches in Dulesgate, Todmorden, to about two inches at Affeside and Harwood, near Bolton.
Hard heavy Stone, full of *stigmaria ficoides*, an excellent material for roads (Gannister)	0	1	2	
Smooth white Clay, sometimes changing into Gannister	0	2	0	
Light-coloured Stone	4	0	0	
Grey Metals	5	0	0	
Black Shale	2	0	0	
Coal (Foot Mine)	0	2	0	Principal mine of Quarlton and Affeside.
Soft brown Stone Floor, containing layers of Ironstone	1	1	0	
Black Shale	15	0	0	
Coal (Bassy), never worked in the neighbourhood of Bury	0	2	3	The chief mine of New Mills. Mellor, Compstall, and Ludworth.
Grey and Brown Shale	6	0	0	
Close bedded Rock, which divides into cubes	3	0	0	
Excellent light-coloured Building Stone, (Woodhead Hill and Lomax Wood Rocks)	7	0	0	One of the best building stones in the coal series. This is about its average thickness, but there are instances of its being much thicker.

	yds.	ft.	in.	
Stony grey Shale	6	0	0	
Very black Shale, containing the *avicula (pecten)*, *goniatites*, *&c.*	14	0	0	
Coal	0	0	9	
Shale Floor	1	0	0	
Coarse-grained Rock	8	0	0	
Dark Shale, full of the *avicula** *(pecten)*, *posidonia*, and *goniatites*, mixed with *ferns*, *lepidodendra*, *&c.*	0	1	6	Principal mine of Buxton, Whaley Bridge, Walmersley, Lomax Wood, Fecit, and Birtle Dean. The lowest mine worth working in the vicinity of Bury.
Coal (Feather edge)	0	2	3	
Rough, or Quartz Rock, full of large rounded Quartz Pebbles (Old Mother Rock of Werneth, &c.)	12	0	0	This rock is often taken for one of the millstone grits. It is exposed at Charlesworth, Werneth Low, Broadbottom, Charlesworth, Blackstone Edge, Birtle Moor, Baldingstone, Cribden, Anglezark Moor, Pillsworth, Holcombe, Turton Tower, Horwich Moor, Grimshaw Delph, Parbold, and Harrock Hill.
Grey stony Shale, often approaching to Flags	25	0	0	Edgeworth, Sunnyside, Rowley Moor, Fo Edge, Summit, Shawforth, and Fullwood, Yorksh.
Rough flaggy Rock, provincially termed "Rag"	4	0	0	
Fine smooth Flags	2	0	0	
Strong brown Stone, parted with Shale, containing thin beds of Flags	50	0	0	
Fine-grained Rock, of a bluish colour	2	0	0	
Grey Shale	8	0	0	

* This and the next named bed of marine shells are very constant, but the first three beds are not always met with.

	yds.	ft.	in.	
Black Shales, *avicula (pecten)*, &c ...	37	0	0	Chunal Summit Tunnel, Cheesden Bridge, Sunnyside, below Holcombe Hill, Brooksbottom, and Withnell.
Coal	0	0	6	
Black Shale	2	0	0	
Coal	0	0	8	
Black Shale	8	0	0	
Black Shale, with layers of Stone...	6	0	0	
Coal	0	1	3	
Dark Shale	4	0	0	
Upper Millstone Grit	60	0	0	Hayfield, Roecross, Saddleworth, Gauxholme, Cheesden Bridge, Brooksbottom, Holcombe, Ramsbottom, New Church in Pendle, and Brinscall.
Dark Shale	40	0	0	Roecross, Tintwistle, and Gauxholme, at which last named place the two small seams of coal are seen.
Coal	0	0	4	
Dark Shale	15	0	0	
Coal	0	0	8	
Dark Shale				Kinder Scout, Tintwistle, Greenfield, Todmorden, Pendle Hill, and Longridge.
Lower Millstone, with its partings...	70	0	0	
Limestone Shale, containing beds of Gritstone, about	300	0	0	Tintwistle, Todmorden, Pendle Hill, and Clitheroe.

With these remarks, I shall now proceed to describe my specimens. In the quarry at Hutton Roof, about four miles from the Burton and Holme Station, on the Lancaster and Carlisle Railway, a well known flag is worked. This stone is covered with markings which, although not described to my knowledge in any published work as the tracks of annelids, I have seen specimens in cabinets which are generally labelled as such.

The position of this flagstone is in the limestone shale. It must be of considerable thickness, as it is exposed to the extent of full sixty feet. The dip is at an angle of 10° E.S.E. and the rock lies a short distance above the carboniferous limestone seen in the vicinity. The beds of stone vary in thickness from the twentieth part of an inch to six inches and more. Upon their upper surface is a meandering trail of about two-tenths of an inch in breadth. This is most frequently found in relief, but sometimes in intaglio. Fig. 1, plate 1, drawn on the natural scale, will give an idea of the nature of the majority of these trails, which cross each other several times and run to a considerable length. The hollow trails are deepest in their middle, and have their margins raised by a slightly elevated ridge of sand.

Besides the trail last described there are two others, namely, a broad one of half an inch wide, and generally straighter, but not so long in its course as the smaller ones; and a double trail, having markings a little less in size than the first described, and about one inch apart, generally running in nearly straight or slightly curved lines. These last somewhat resemble the track of small crab on the present sand beaches.

Some of the American tracks are so much like those at Hutton Roof that a description of the one would nearly suffice for the other.

At p. 256 of the Proceedings of the American Association for the advancement of Science, Professor Hall, in describing the tracks found on thin layers of sandstone, alternating with skaly beds, in the lower part of the Clinton group in the central part of New York, which he considers to have been made when the bed was exposed above water, or beneath shallow water only, proceeds as follows:—"The general character of the trails here noticed is that of a meandering furrow, more deeply depressed at the two sides, elevated at the centre, and margined by a slightly elevated ridge of sand which appears to have been pushed outward in the progress of the animal. Others of them are a simple furrow with the deepest depression in the centre; while others are fimbriated or ciliated along their whole extent; proving that they were produced by several distinct species of animals. In their general character some of them are not unlike the trails made by *natica* or *littorina*, and others are more like the meandering trails of *idotea*. In many the great length of the meandering line, which crosses and recrosses itself in many times, seems to indicate that the animal moved rapidly over the surface; in others the trails are larger, and the animal probably moved much more slowly, the length being often limited to a few inches. These trails vary greatly in size—from a diameter of half a line to half an inch,—and the smaller ones as a general rule are the longest, and shew more recrossings than the larger ones."

In the specimens from Hutton Roof no evidence of the annelid or mollusc is found, and the trails are the only remains left of the creatures which made them. Doubtless at the time of the deposition of the beds now forming the flags, both these departments of the animal kingdom existed, if we may judge from the organic remains in strata found both above and below those in which the fossils were met with; and the inhabitants of the *buccinum gibsoni* and other shells found in the limestone shale, could have made a trail of about the same size as those of the specimens. From the meandering character of the trail, crossing itself several times like that of the *littorea littoralis*, it bears more evidence of having been made by a mollusc than an annelid. The bottom, too, of the trail is flatter, and not so concave as that of a worm generally is. This also appears to have been the opinion of Professor Hall, with regard to the American specimens before alluded to.

In my cabinet is a slab of flagstone from a quarry belonging to Mr. Jonathan Whitaker, at Dyke Nook, between Hebden Bridge and Keighley. The stone is much used for making grindstones. Its upper surface is thickly covered with meandering trails in relief, similar to the smaller ones before described at Hutton Roof, except that they are about four times the size of those specimens, and do not cross each other so much, but have a straighter course. The upper or relief side of the trail is marked with transverse striæ, with a slight ridge in the centre; the concave side is rather flat, and has a ridge in the middle. The exact position of this flag in the carboniferous strata, I am unable at present to give.

In the beds of flags found in the lower division of the Lancashire coal field, are some singular markings which have not yet been much investigated. They occur both in the upper and lower beds, namely, the Old Lawrence and the Haslingden flags, and are evidently of different origin.

In the upper bed of flagstones, much used in this neighbourhood for in-door floors, and having very smooth faces, are often seen numerous indentations, passing through several laminæ of stone. These shew an orifice on their upper and a projection on their under surface. An example of these marks is figured in the paper by the author, printed in vol. viii. (new series) of the Transactions of the Society, at p. 170. They are very common both on the Lancashire, Cheshire, and Yorkshire flags of the upper series, but little, if any, attention has been hitherto directed to inquire into their origin, and in my former paper no allusion was made as to the animal which had caused them.

During the formation of the tunnel on the Bury and Liverpool railway at Upholland, in the upper flags there I collected some of the stones, having very distinct markings on their surfaces, and upon breaking them crossways, obtained evidence as to the probable cause of the holes in these flags at least, if not of those found in other places. But it is likely that other specimens from different localities, if carefully examined, will afford similar evidence. The upper part of the holes in the larger specimens is about eight-tenths of an inch in diameter, and gradually tapers to a depth of nine-tenths, and then, by a curved orifice of two-tenths of an inch, is connected with another conical hole like the first. These holes, a good example of which is shewn in fig. 2, plate 1, drawn on the natural scale, appear to shew that they were formed by an animal of Cuvier's division of *annelides* of the second family, or *dorsibranchiata*, where the external breathing organs or gills, often resembling beautiful feathery tufts, are attached in pairs, either to every segment of the body, or to a certain number of middle segments. The organs often display the most elegant varieties of form and the richest colours. To this order belong the majority of the present marine *annelids*, and, among the rest, the common lug worm, *arenicola piscatorium*. It is to this last named annelid, or one nearly allied to it, that I am inclined to attribute the holes above described. The fossil holes are smaller than the recent ones. With this exception, the only difference that I can detect betwixt the fossil holes and those at present found on our sandy shores is, that there are no traces of the coils of sand at the vent end of the hole, which so generally accompany those of the lug worm at the present day. These may have been formed under water, and afterwards washed away, but certainly I have not yet been able to detect any near the fossil specimens. The animal which inhabited the hole appears to have drawn in the water and sand by one opening, and ejected them from the other.

For a provisional name I have designated the animal which made the holes *arenicola carbonarius*.

Upon the surfaces of some of the finer beds of the lower flag deposit are often seen numerous depressions of a more elongated and bent form than those last described as occurring in the upper flags. Some of them are about an inch in length and a quarter of an inch in breadth. Near to these are sometimes seen traces of a furrow or trail, more or less distinct according to the nature of the flag, whether it is fine and smooth-faced or otherwise. They are seen in the flags of Edgeworth near Bolton, Fo Edge near Bury, Shawforth near Rochdale, and other places where the lower flags are extensively worked. For some years I have been of opinion that these deep impressions were the casts of a bivalve shell, and the shallow ones its trail in the sand, when the latter was in a soft state.

During the cutting of the Manchester and Huddersfield Railway through the lower flagstones at Scout Mill, between Staleybridge and Mossley, I found a specimen which gave me decisive proof that I was not mistaken in my former opinion. In this specimen, figured at plate II. fig. 1, drawn on a scale of one-seventh the natural size, the casts of several shells, apparently of the genus *modiola,* with their trails, are distinctly seen. The curve which the animal made in its track much resembles that of the *psammobia solidula* on the soft mud of our present coasts, and presents a very marked difference to the meandering trails of the *littorina* and some other univalves, to which the most common trails on the flags of Hutton Roof, if they are not worm marks, must be referred.

The whole appearance of the trail leads me to believe that it was formed under shallow water, just as we now see individuals of the genera *psammobiæ* and *naticæ* make trails upon the mud at the bottom of the pools on the sea shore. And in confirmation of this view I may add, that the thin beds of clay separating the deposits of flags shew no evidence of desiccation by cracks in them, which they would have done if they had been exposed to the sun's rays.

In a paper by me, printed in vol. viii. of the Society's Memoirs, at p. 171 is figured the cast of a small annelid of nearly the shape of the letter S, about an inch long and a line in breadth. It is merely a cast of the animal itself without any trail, in a bed of fine sandstone, and found by me in the lower flags near Todmorden.

I shall now proceed to make some observations on a spiral fossil shell frequently found in the Lancashire coal field, and long known by the name of *microconchus carbonarius.* Mr.

Martin, in his Petrificata Derbiensia, figures this shell as *conchyliolithus helicites, (pusillus* plate 25,) and states it to be of rare occurrence in the coal shale near Chesterfield. The occurrence of it near the last-named town, in the lower part of the middle division of the coal field, I can fully confirm; but it is far from rare, being there met with in considerable abundance. Sir Roderick Murchison, in his Silurian System, at p. 84, in speaking of the limestone found in the higher part of the coal field near Shrewsbury, states,—"That the characteristic fossil of the limestone is a very minute discoid univalve, resembling on first inspection *planorbis nautilus,* Fleming, and with it is a small bivalve resembling a *cyclas.*"

At p. 88 of the Silurian System, Professor John Phillips, in describing the Ardwick limestone, states,—"Among the shells the most characteristic is a microscopic spiral shell of few volutions, which touch one another like the *planorbis* when young, but when old are exhausted into a free tube like *vermetus,* or rather like *vermilia.* The shell is sinistral like *planorbis,* but sometimes shews proof of its being attached on one side like spirorbis—lines of growth strong, somewhat irregular, deficient in parallelism, and oblique to the axis of the tube as in *planorbis;* faint spiral striæ can just be seen. This shell, which I have identified with your Salopian planorboid shell, is also probably the same as a species I have seen from the coal measures of Fitzgerald's colliery,* near Manchester, as well as from the lower part of the Yorkshire and Newcastle coal field."

Dr. Hibbert,† in noticing this fossil, states that it appears in a crushed and broken state. In this form they exhibit a

* After many years' search I have certainly found the fossil at this place, but in nothing like the abundance as at the Bradford and Clayton collieries, where it occurs in great profusion.

† On the Freshwater Limestone of Burdiehouse, &c. Transactions of the Royal Society of Edinburgh, vol. xiii., part 1, p. 180.

sort of spiral organization, by no means unlike that of the *planorbis* or *spirorbis*, to which they were referred by an eminent conchologist, whose opinion regarding them I have consulted. But on renewed examination of these remains, which, owing to an infiltration of calcareous matter, have had their forms tolerably well preserved, I am now inclined to place some doubt upon the judgment which had been passed upon their character. The external form of one animal most resembles that of the *nautilus*, but we are totally precluded from identifying it with that class of *mollusca*, as the internal constitution of its shell shews no septa whatever, but on the contrary, approaches to that of the *planorbis*. It may, perhaps, be considered as a new genus altogether—referable to *mollusca*."

Mr. Morris, F.G.S., in his excellent Catalogue of British Fossils, also classes it amongst *mollusca*.

Professor Goldfuss* considers the *microconchus* an annelid, like the *spirorbis*, and describes it as *S. omphaloides*. Col. Portlock, in his Memoir of the Geological Survey of Ireland, describes it under the same name. Sir Charles Lyell, in the last edition of his Manual of Geology, at p. 324-5, still calls the fossil *microconchus carbonarius;* but describes it as "the microscopic shell of an annelid of an extinct genus allied to *serpula* or *spirorbis*."

From the above quotations it is pretty evident that considerable doubt has existed as to whether or not the *microconchus* should be classed with *mollusca* or *annelata*.

In the Lancashire coal field this fossil is found from the lowest up to the highest strata—generally in black bass. In the roof of Mr. Stock's coal at Shaly Brow near Billinge, it constitutes a bed of about six inches in thickness, and is mingled with the remains of fishes. In the thick bed of large shells lying about fifty yards above the Arley Mine,

* Howse, T. N. I. C., vol. i. p. 259. 1848.

and indeed in all other beds of shells which have been generally classed under the genus *unio,* it has been found. Most of the black shales forming the roofs of the coals in the middle and upper coal fields, and the limestones of Ardwick, yield it. But, with the exception of Shaly Brow, it is the most plentiful in the roofs of the yard and three-quarter mines of Bradford near Manchester, mingled with a mass of *cypris,* and detached bones, scales, and teeth of fishes.

The genus *microconchus* probably had better for the present be divided into two genera, namely, *spirorbis* and *serpula;* under spirorbis, I propose to class,—

1st. The small one figured by Sir R. Murchison, found in the shales and limestones of Ardwick. This is sometimes attached to plants and shells found in the shales, and has evidently lived as a parasite both on floating plants and shells, lying at the bottom of the waters just as the common *spirorbis* now found on our shores does. The specimen described in plate II. fig. 3, is one-twentieth of an inch in diameter, and was found by me on a fossil bivalve shell from the roof of the Four Feet Mine at Bradford near Manchester. I propose to call it *spirorbis carbonarius.*

2nd. *S. omphaloides,* of Goldfuss and Portlock. A large species, found in many places, especially amongst the bed of large bivalve shells lying above the Arley Mine at Wigan, and other places, and the shales of Shaly Brow. This species apppears to be identical with the one found by Martin, near Chesterfield, and figured by him under the name of *conchyliolithus helicites.* The specimen described in plate II. fig. 4, is two-tenths of an inch in diameter, and was found by me in the roof of the lower seam of coal in Mr. Stock's colliery at Shaly Brow.

The large uncoiled shell appears to me more properly arranged under *serpula.* It is by no means so common as the two species of *spirorbis* previously described, and I have not yet found it attached to fossil plants or shells like those, but free. My specimen figured in plate II. fig. 2, twice the natural size, is from the limestone of the upper coal measures at Ardwick. It is very like the shell mentioned by Professor John Phillips at p. 88 of the Silurian System, previously quoted, but larger in size. This author classed it with one, if not both of the two species of *spirorbis* before mentioned, and considered it as merely a specimen of more advanced age. However, I have not met with any graduation of the *spirorbis* into *serpula* either in recent or fossil specimens. The commencement of the fossil shell in its first volutions is like that of the *spirorbis*, but it then extends into a free tube like *vermilia*. My specimen is three-tenths of an inch in length, and one-twentieth of an inch in diameter at the broadest portion of the shell. It is covered with irregular striæ, placed rather oblique to the axis of the tube, which is cylindrical. From its characters and the places where it is found, both differing from those of the *spirorbis*, I propose to call it the *serpula carbonarius*. It resembles *serpula* more than anything else; and I have not yet found it attached to fossil shells or plants like the *spirorbis*.

The two species of *spirorbis* described in this paper, from their external characters and the places where they are found attached to the surfaces of shells and plants, lead strongly to the conclusion that they belonged to parasitical annelids like the common *spirorbis*, (*serpula spirorbis* of Penn. Brit. Zool., No. 155, tab. 91, fig. 155.) But I am bound to state that I have seen a specimen of a fern from the Lancashire coal field belonging to Mr. Matthew Dawes, F.G.S., with several shells not to be distinguished from the small species previously described embedded in the substance of the fossil. In my own cabinet there is a specimen of a small *sigillaria* from the roof of the Riley Mine at Captain Fold near Heywood. The substance of this fossil is clay ironstone, but the epidermis of the plant is converted into coal. Under the coaly envelope are numerous specimens of a shell like the *spirorbis* *omphaloides,* embedded in the body of the fossil two-tenths of an inch in depth. It is possible in both these instances that when the fossil plants were in a soft pulpy state, and the shells were attached to them, superincumbent pressure might have squeezed the shells into the substance of the plants. But in both cases we should expect to discover some portion of the coaly matter squeezed in as well. This I do not find.

Now is it probable that some of the shells described as belonging to the genus *spirorbis* were inhabited by boring molluscs or worms? In the bed of shells before alluded to as occurring above the Arley Mine at Wigan, and generally termed large *unios,* (?) are many specimens having holes bored in them,—thus plainly shewing that boring molluscs or worms did then exist. In this bed the *spirorbis* abounds as well as the so-called *unio.* So after all the disputes as to the nature of the *microconchus,* it may possibly be that in some species at least its inhabitant was a mollusc allied to *teredo,* and not an annelid, as has generally been supposed.

In former communications* published by the author he has brought forward both the fossil fishes and the fossil plants, to shew that the waters of the carboniferous epoch were nearly if not altogether of a marine character. The facts described in this paper of the meandering trails of molluscs, the burrowings of worms, the occurrence of shells pierced with boring animals, and the parasitical annelids found attached to plants and shells, all tend to the same conclusion. But beyond all other proof of the marine character of the water of the carboniferous age, is the water itself now found mixed with the coal, and where it has remained for countless ages pent up and hermetically sealed. In deep mines, where the seams of coal have not been subjected to the percolation of surface water, but protected by compact beds of indurated clay, the water is nearly always saline, and contains iodine

* Transactions of the Manchester Geological Society, vol. i. p. 173; Memoirs of this Society, vol. viii. (new series) pp. 24 —

and bromine, together with all the salts usually found in the waters of the present ocean.

The numerous trails throughout successive strata, and the preservation of the habitations of such frail creatures as worms, shew that the deposits took considerable time in their formation and were made in great quietude. In fact every thing indicates that the deposits which we have been investigating went on from time to time with as great regularity, and in very nearly the same manner, as beds of sand and mud are now forming in the ordinary course of nature on and near our present shores,—although we cannot well distinguish regular tidal deposits, such as are now taking place.

In bringing this dry, and I fear uninteresting, paper to a close, I wish to direct the attention of my readers to the trails of molluscs and the burrowings of worms now to be seen on our sea shores. And for this purpose I cannot do better than refer them to a charming little work of Dr. Harvey's, intituled "The Sea-side Companion," and conclude with an extract from it. At p. 25 of his book he says,—

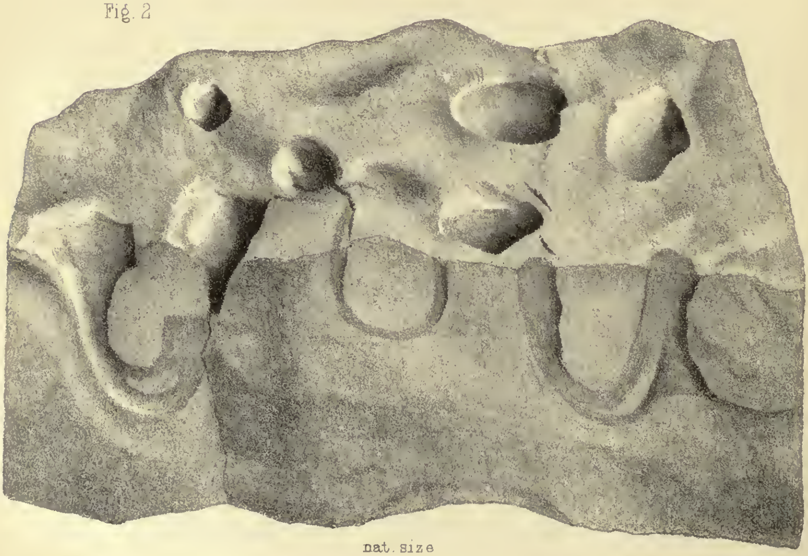
"The foot-prints of sea birds on the sands of the shore are often unnoticed, and are swept away by the first returning wave. So are the tracks of trailing shell-fish, which may sometimes be seen furrowing the surface of fine hard sand in considerable numbers. The common yellow nerite *(littorina littoralis)* is a frequent maker of these trails, as it moves its station from one small rock to another, patiently cutting a road through the sands as it proceeds on its journey. These marks, and the undulation left by the water on the surface, where regular minute ridges of sand follow each other in an orderly manner, like the furrows in a field, appear of so fugacious a nature as to be undeserving of notice. The retreating wave has left them behind, and the returning will sweep them away, and all be a smooth surface again. Yet, in these fugitive markings of the sand the geologist traces a resemblance which links them with time immeasurably distant in the past history of the world, and with impressions on rocks which have outlived the decay of centuries, but which were, in their origin, of no more apparent stability than these marks in the sand, or than our own foot-prints. When a surface of sandstone rock is uncovered, it very frequently exhibits markings of a nature precisely similar to what we every day meet with on the sandy shore. There is the *ripple-mark*, defined with equal regularity and sharpness—we see where every wavelet of the antediluvian ocean did its work;—there are the sinuous roads, cut out by the antediluvian molluscs now visible in relief, by the mud which has silted into them;—the worm-like heaps of sand, which mark the position of the worm, or of the testaceous mollusc, are equally obvious in the sandstone, and on the recent shore;—the very rain-drops which impressed the sandy surface thousands of years ago have left their record on the surface of the rock. When we see all these appearances on the newly turned up rock, and find similar markings on the flat sands of the sea, it is impossible to avoid connecting the two observations, and admitting that in what passes under our eyes as a daily occurrence on the sands, we find the explanation of the geological phenomenon. The sandstone rock, hard as it now may be, was once a beach, as impressible as that in which we may now be leaving our foot-prints. And though, in thousands of cases, these foot-prints will be swept away by the next flow of the water, it may so happen that they will remain. And it is a wonderful circumstance that all trace of some of the gigantic animals which once inhabited the world has perished from the knowledge of mankind, save only the track of their foot-prints left in what was then adhesive mud, but which successive ages have converted into hard stone. If Robinson Crusoe was powerfully affected by meeting with the naked human foot-print in the sand, what a crowd of thoughts are awakened by discovering, in the hard rock, this only evidence of a gigantic animal. A true poet has said,—

PLATE. I.

Fig. 1.

nat. size

Fig. 2



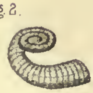
nat. size

PLATE II

Fig. 1.

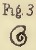
1/7

Fig. 2.



2 diam.s

Fig. 3.



2 diam.s

Fig 4.

2 diam.s

'It is the soul that sees: the outward eyes
Present the object, but the mind descries;
And thence delight, disgust, or cool indiff'rence rise.'

"We may live among the grandest scenes of nature, or may visit the noblest monuments of art, and remain insensible to their beauty or sublimity. Differently affected, we may find in the barren sands of the sea shore enjoyment of the purest character, and speculations which, rising from nothing more important than the trail of a sea slug, will lead us to contemplate, and in some measure to comprehend, some of the most extensive operations of nature, and bring under review unnumbered ages, past, present, and to come."

Explanation of the Plates.

Plate I. fig. 1. Upper surface of a flag of sandstone from Hutton Roof, shewing the trail of a mollusc, (?) drawn on the natural size.

Fig. 2. Upper surface and side view of a flag of sandstone from the Bury and Liverpool Railway near Upholland, shewing the holes of the *arenicola carbonarius*, drawn on the natural size.

Plate II. fig. 1. Upper surface of a flag of sandstone from Scout Mill near Stalybridge, shewing the casts and trail of a bivalve shell, drawn on a scale of one-seventh the natural size.

Fig. 2. *Serpula carbonarius*, from the upper carboniferous limestone of Ardwick, on a scale of twice the natural size.

Fig. 3. *Spirorbis carbonarius*, from the roof of the Four Feet Mine, Bradford, twice the natural size.

Fig. 4. *Spirorbis omphaloides*, from the roof of Mr. Stocks' coal at Shaly Brow, twice the natural size.

XI.—*A Biographical Notice of Peter Clare, Esq., F.R.A.S.* By the Rev. H. H. JONES, F.R.A.S.

[*Read April 6th,* 1852.]

THE late Peter Clare, Esq., was born in Manchester, in the early part of the year 1781, but the exact date of his birth as far as we are aware is not known. While quite a youth he was accustomed to assist his father, who was in the habit of giving occasional lectures on electricity, and some kindred subjects in natural philosophy, illustrated by experiments.

The son, in consequence of his early habits of thoughtfulness and inquiry, was not unfrequently admitted to the meetings of the Literary and Philosophical Society of Manchester, while he was yet ineligible for membership on account of his minority. And though he had arrived at the requisite age some years before, his modesty held him back till 1810, in which year he was regularly proposed and elected an ordinary member of the Society.

Commending himself, by his constant attendance and uniform assiduity, to the approbation of his philosophic friends, he was in the course of a few years made a member of the Council, or as it was then designated, "The Committee of Papers." Subsequently (I believe it was in the year 1821) he became one of the Secretaries; and during the last several years of his life, he held the office of Vice-President of the Society; the duties of which office he continued to discharge with unremitting attention till disabled by his last fatal illness.

In the year 1841 he was made a Fellow of the Royal Astronomical Society. And though he was constitutionally unfitted for the frequent and persevering use of the telescope, and his residence in Quay-street subjected him to great local disadvantages, yet in the discoveries and progress of astronomy he continued to take a keen and unabated interest to the very last.

It is true Mr. Clare was not a profound student, nor was he a frequent contributor to the publications or memoirs of any of the literary or scientific institutions with which he stood connected. But he was an ever active friend to those who took a more prominent or adventurous part than himself in the proceedings of such societies,—was thoroughly imbued with a taste for philosophical investigation,—and was acknowledged by all who knew him intimately, to be a man of very varied and extensive information.

But that which (in the estimation of many) will form the most distinguishing circumstance in the life of Mr. Clare, is the fact that he was for many years the most intimate friend and almost constant companion of Manchester's greatest celebrity—the late Dr. John Dalton. The high estimation in which he was held by this celebrated man is sufficiently evinced by the Doctor's leaving him a handsome legacy, and also appointing him one of his executors.

In the religious and political circles of the day, Mr. Clare was extensively known as a prominent, zealous, and untiring member of the anti-slavery committee. In this capacity he was honoured by being placed on several deputations to the Government, while measures for the abolition of slavery were under their consideration.

In person Mr. Clare was a trifle below rather than above the middle stature.* He was always remarkably well dressed; and his bland and portly aspect was calculated to produce an

* Since the above was written, an excellent portrait of Mr. Clare, by Bradley, has been bequeathed to the Literary and Philosophical Society by the late Samuel E. Cottam, Esq., for many years an intimate friend of Mr. Clare, and whose loss also the Society has now to deplore.

impression in his favour, which occasionally arrested the attention of strangers, and induced them to inquire for his name. While in health he was uniformly cheerful. In the social circle he was always entertaining, and not unfrequently facetious, having a good memory and a large fund of humorous anecdotes and amusing narratives at command. As a natural consequence, his company was often sought and always acceptable.

Like his illustrious friend Dr. Dalton, he was brought up a Quaker. To that denomination he adhered through life. But he never unseasonably obtruded his religious opinions upon others. In fact, he always comported himself with the unaffected ease and urbanity of a real gentleman, continually exemplifying in the mild and "even tenor of his way" the beautiful sentiment of old Geoffrey Chaucer,—"He who ever intendeth to perform all kinds of gentle deeds, is the greatest gentleman; and he who will perform none of them—

He is not gentle, be he duke or earl."

Mr. Clare was never married; and has left very few near relations to mourn his loss. His last illness was long, but not painful. The disease under which he finally sank is believed to have been an affection of the heart. He died on Monday, November 24th, 1851, in the seventy-first year of his age, and was interred on the following Sunday morning in the "Friends'" burying ground, Mount-street, Manchester. His remains were followed to their last resting place by a numerous body of his own denomination—by the President, Council, and other members of the Literary and Philosophical Society, and a large concourse of spectators.

Peter Clare was in every sense a truly respectable and much respected man,—an ornament to the connection in which he moved,—and sincerely regretted by a wide circle of acquaintances and friends.

XII.—*On the Air and Rain of Manchester.*

By Robert Angus Smith, Ph. D. F.C.S.

[*Read May 4th*, 1852.]

Last year I read a paper on this subject, somewhat different in title, to the British Association. As a very imperfect abstract was printed I have again written the paper, giving no new facts, but using different words.

My object is to shew that there are impurities in our atmosphere which may be discovered by chemical analysis, and that the senses and general impressions are not at fault when they speak of the peculiarities of a town's atmosphere. I had shewn in a former paper that it was not a mere fancy to suppose that the air of crowded rooms was tainted, and that it contained a substance capable of nourishing organic forms, and therefore in itself organic; and although by no means a new idea, as may be shewn from old writers, I consider it of importance that these things should not rest merely on ordinary observation, but should be more and more brought under the domain of careful experiment.

It had often been said that we were unable to tell the difference betwixt good air of the finest mountain side, and the worst air of the hospitals,—or rather, we should now say, of the infected dens of large towns, so well described in various forms, of late years, to the public. It seemed to many as if the eye had obtained a mysterious power of seeing what was scarcely capable of being proved within the domain of substance, and the smell had a power of observing what was more an influence than a positive thing. These modes of thinking are too indefinite to be considered as opinions, and they belong also to that state of mind so common to early ages, and not uncommon in our own times, which confounds the idea of substance and elements with the ideas of power and character. These words may certainly be made to bear a closely approaching signification when viewed from a metaphysical point of view, but in physical science their limits are distinct.

The air has been a fertile source of inquiry and speculation in all times; the early writers seem lost in the vastness and vagueness of the subject, and the history of opinion upon it, up almost to the present century, is like the history of some non-physical or metaphysical subject. It is a common notion that our mental part must resemble air, and we might readily make an interesting history of the indefinite ideas and confused reasoning which introduced into our language such expressions as "the spirit of wine" and "pneumatic chemistry." But here, as in many other cases, whilst the true solution has been difficult and late, the main points have been seized very early, and whilst we may fairly object to, or smile at the use of phrases which shew our opinions to be taken from those who thought, like Anaximenes, that the soul was aërial, we scarcely differ from him when we say, as we may fairly do, "that plants and animals are made of air and return to air."

We cannot say much for the increase of clearness of thought when we compare this with a description of air written (per Johnsonum Chymicum) in 1552. "Aer est spiritus, spiritus est ventus," "The air is spirit, spirit is wind." Nor even coming later, to the time of Stahl, who lived at the beginning of the last century, and who had followers, great men, also in this century, do we see it much improved. Stahl says,—"Air is nothing but æther mixed with aqueous effluvia and the exhalations of solid bodies." Also he calls it in better style, "a light dry body, mixed with various particles of saline, sulphureous, and aqueous salts." Here, however, is brought prominently forward an opinion of long standing, the mixture of solids with the air, giving rise to the expressions, "lighter and denser," "moist and earthy," "mixed with the exhalations of the earth." "Terreni halitu miscens" are Pliny's words.

Des Cartes found it necessary, therefore, to give a more minute description of air: "We know that air can be nothing but a collection of particles of the third element—that it is a fluid very rare and pellucid," distinctly bringing it under the class of ordinary material bodies, and taking it from the sphere of mind.

The great difference of different airs, and the effect they have in the system in raising or depressing the spirits, have no doubt been causes why air should have had many indefinite notions connected with it, independent of the ordinary want of a correct definition of matter, and the peculiar difficulties in the case of a body which cannot be seen. When a person is depressed in one place, and elevated in another, he is not unwilling to believe the very poetical idea of Heraditus that "we receive our life by breathing in the air the soul of the world." And to a great extent there is a practical truth in this, as we are often found to possess more or less life according to the condition of the air.

Modern chemistry has gone far towards proving the correctness of ancient impressions, that the air goes with the blood through the whole body, and some have almost gone as far as a Greek philosopher, who said that "the soul is in the lungs."

As so many opinions have already been delivered on air, it is not easy for any one to bring forward more beautiful or more expansive ones; there is room, however, for experiments to make our ideas more definite. We hear of pure and impure air, but these phrases do not convey the same meaning to all persons. Impure air is simply air with impurity in it; to some it means a different kind of air inherently impure. This vague and alchemistic notion, which did not distinctly define, was combatted in speaking of compounds generally, even by Roger Bacon, but it was not until Dalton's time that any distinct notions of compound bodies became general, notwithstanding Newton's definition of atoms.

The number of analyses of air in order to ascertain its oxygen and nitrogen, have been very great, and many also exist which determine the carbonic acid; little, however, has been done in ascertaining the other possible contents, and some eminent names have rather discouraged the idea of finding any thing, because if any thing else did exist, the amount would be too small for analysis to detect, and therefore too small for the body to be affected by it. Some such mode of reasoning has been current, but it is not in our power to tell what is the smallest amount of matter which will affect the system, and we know that exceedingly small doses affect us if taken repeatedly, although that effect is not equal to the effect of taking the whole at once.

Whatever chemistry or scientific men have said about the air, or indeed about any thing else, common sense and ordinary observation have had their force in no way diminished, and it is wiser for science to explain the large generalizations of common sense and the teachings of instinct, than to run counter to them; by which means it produces on one side at times extraordinary scepticism, and on the other extraordinary credulity.

Our senses are often much superior as tests to chemical tests, that is, we can perceive by our senses very often less than we can test; but it is not always the case, and when the amount is too small for either mode of observation, experiment has the great advantage of being able to condense and to accumulate, and so bring everything within the region of the sight. But it is not to be supposed that because we bring within the limits of a glass vessel enough of the impurities of the atmosphere to allow us to see them, there is therefore any greater proof that the air had these impurities in them. It was well known before. The action on the system for so many years, producing almost a different race of men, is a stronger proof of a chemical action than any thing done in a bottle. This difference of feeling which we have in different atmospheres, may be said to be perceived by our *chemical senses,* as the effect is produced by decomposition in the system, and not by physical contact, otherwise we should feel the pain on the skin, or at furthest in the lungs. After breathing certain gases, either sulphuretted hydrogen, sulphuric acid, nitrous gases, muriatic acid, or chlorine, a certain lassitude and an inclination towards anxiety is felt; certain decompositions have been put in motion, and certain others have been arrested, which produce this result in the system, and we have been very slightly inconvenienced by their action on our ordinary senses. But it may happen also that our ordinary senses have perceived nothing at all, whilst illness, elevation, or depression of some kind, which are modes by which we feel a chemical action, prove it to have taken place.

The air of our towns generally seems to waver between these two states; in some cases it is shewn to be hurtful by our ordinary senses, in others it can only be felt in a secondary manner, or by what it is fairer to call our chemical senses. Of course I leave out here the fact that it is almost at all times visible to the eye, but there are differences of opinion as to the effect of that portion which is visible.

At the same time it must not be forgotten that there are advantages in towns which cannot be obtained out of them by the most of people—dryness caused by good drainage, and the cleanness of good sewerage.

As I said before, I have nothing which I can call actually new to bring forward here, but it does still present some novel feature. The air was not examined as such, because I had not proper conveniences for the experiments, and I was compelled therefore merely to examine the rain. All the rain was found to contain sulphuric acid in proportion as it approached the town, and with the increase of acid the increase also of organic matter.

The existence of albuminous compounds may be traced in the rain, however carefully collected, and the still further vestiges of living creatures, minute animalcules, may be found also. These creatures are sufficient of themselves to shew the existence of phosphates, whilst sulphates and lime may be readily obtained. In examining the Thames water I often found that the readiest way of collecting the phosphates and magnesia was to wait for the animalcules to do it. When the residue of the rain is burnt, an abundant evolution of ammonia may be obtained; but I have not ascertained the amount, because it varies much, and I do not well feel able to collect all the ammoniacal salts which may have existed in the rain, as so much loss is caused by evaporation, even if an acid is present. All results hitherto obtained must have been approximative and too low.

This organic matter, however, is capable of decomposing and of forming ammonia when it falls upon the ground, and of furnishing food to all kinds of plants. There is enough therefore to grow plants scantily, although experience shews that there is not enough to produce a crop of any value. I do not regard it however as the object of nature to manure the land by rain—one more important and practical is to purify the air; and there is enough of evidence to shew us that places entirely without organic matter may become covered with it, and also to shew us that plants nourished even by rain water only may be made to grow.

This shews also the possibility of large quantities of impure matter being kept afloat in the air, indeed it is scarcely possible to obtain the vapour of water without some such impure matter. The organic matter found in the rain seems to be in perfect solution, and no doubt the more decomposed portion of it at least is entirely so, but an exception must be made of that which is alive.

It becomes clear from the experiments, that rain water in town districts, even a few miles distant from a town, is not a pure water for drinking, and that if it could be got direct from the clouds in large quantities, we must still resort to collecting it on the ground in order to get it pure. The impurities of rain are completely removed by filtration through the soil; when that is done there is no more nauseous taste of oil or of soot, and it becomes perfectly transparent.

The presence of free sulphuric acid in the air sufficiently explains the fading of colours in prints and dyed goods, the rusting of metals, and the rotting of blinds.

It has been observed that the lower portions of projecting stones in buildings were more apt to crumble away than the upper; as the rain falls down and lodges there and by degrees evaporates, the acid will be left and the action on the stone be much increased.

I do not mean to say that all the rain is acid—it is often found with so much ammonia in it as to overcome the acidity; but in general, I think, the acid prevails in the town. But even if alkaline when it falls, it becomes acid on standing, and especially on boiling down, as the ammonia in these cases is separated from its acid.

A specimen taken in Greenheys fields, half a mile from the extreme south-west of Manchester, wind blowing west, had a peculiarly oily and bitter taste when freshly caught. A person to whom I gave some of it to taste, supposed it had been put into a glass in which castor oil had been put. I had collected the water in a large meat dish, which had been very carefully cleaned, and was then set on a stand about two feet from the ground, during the rain. Thinking it possible that some fatty matter might have been adhering to the vessel in spite of all my care, and not being inclined to believe that such an amount of impurity could be found in that place, I used a platinum basin, which was carefully cleaned, and, to prevent all mistakes as to organic matter, kept red hot for some time. There was however no difference to be perceived from that collected in the larger vessel. The rain was very alkaline, and contained scarcely a trace of carbonic acid.

Boiling removes all taste, and standing alone removes the taste of the oily matter and leaves only the taste of smoke. The smoke here shews that it was not out of the range of chimnies, although the wind was west.

The taste was that of the flattest and most insipid water, which could not be drunk with pleasure, independently of the nauseous taste.

The water was very clear, but on standing it produced and deposited a number of organic bodies of the monad kind, small enough certainly when seen by themselves, but in clusters large enough to be seen lying at the bottom of the vessel.

The clear water above was a solution of organic and inorganic substances, giving the following results:—

Organic matter	2·625 grs. per gallon.	
Inorganic "	·875 1·33 2·100	in three experiments.

By boiling the carbonate of ammonia is driven off, at least this seems the only way of accounting for the loss of alkalinity.

On burning the residue after evaporation, ammonia is given off, and a strong smell of feathers, characteristic of albuminous compounds.

The ash is alkaline, with fixed alkalies, like the ashes of plants and other organic matter.

Cavendish-street, June 8th, 1851.—The taste of this water, collected of course directly into the vessel, was the same as that which comes from the roofs of the houses. The taste is nauseous and chiefly of smoke.

It contains many of the green monads, singly and in groups. These increased immensely, and were in numbers much greater than in the field rain. There were also some lengthened bodies somewhat resembling the gallionella, but I cannot speak with certainty of the species.

This water is acid, and on boiling becomes very acid, until it may be readily tasted as sour.

The residue when burnt gave off ammoniacal vapours, and shewed also the presence of albuminous compounds. The sides of the vessel were covered over with an oily or tarry substance.

The ashes were neutral, and consisted of sulphates; sulphate of lime and soda being amongst them.

These two specimens are characteristic of the places; they are not extreme points by any means. One is not very far in the town, and the other is not very far out of the town. I am sorry I have not obtained extreme cases, but the difference is sufficient as a point to start from. The one leaves alkaline ash, the other neutral ash. In the fields the amount of acid is not sufficient to neutralize the bases which are in union with the organic matter, and the residue is therefore alkaline; but in the town the amount of acid is equal, or in excess; what is in excess is driven off, and enough remains to saturate the bases, which become then neutral salts.

The increase of amount of organic matter is not so apparent from the table of quantities which I have drawn up; but I rely more on observing these living creatures, which are the sure indications of its presence. And they shew also that if there was not a great increase of it in the town, it was at least in a state peculiarly organizable.

Again, Greenheys fields, on the same day.—This water has a blackish deposit; a few monads may be seen at once; taste when first got very greasy; after standing a while this taste becomes bitter, like rotten leaves; flat, like all the specimens; sickly taste begins when the greasy and bitter tastes are gone.

Alkaline also; alkalinity lost by boiling.

Nitrogenous fumes obtained on burning the residue.

Residue as before, alkaline.

Timperley, six miles distant.—Abundance of green matter at the bottom of the glass; an immense amount of green monads, mostly separate, but some in clusters.

Gave off alkaline fumes when the residue from evaporation was burnt.

Ash then strongly alkaline.

This water was strongly alkaline, and was farthest from the town; it had, however, a great deal of organic matter in it—as much as any—so that the acid seems so far to be a surer guide to the neighbourhood of the town.

Park-street, outside of the town, south-west.—Matted confervæ appeared in this specimen, on standing, with many green spots stationary and in motion.

The water alkaline, but acid on boiling.

The ashes neutral.

We are here therefore still within the town influence, but it appears that in the outskirts of the town the acid is neutralized in a great part with ammonia, as the rain does not become acid until that is driven off.

We may therefore find easily three kinds of air,—*that with carbonate of ammonia in the fields at a distance,—that with sulphate of ammonia in the suburbs,—and that with sulphuric acid, or acid sulphate, in the town.*

I need not minutely describe each specimen which I collected; there is much similarity when from the same district.

AMOUNT OF INORGANIC MATTER IN A GALLON.

Greenheys	.875	2.100
Cavendish-street, 8th June		1.050
" 9th "		5.6
Park-street		.21
Timperley		3.937
Greenheys fields		2.1
Cavendish-street again		2.8
Moss-side		.8
Greenheys fields		2.333
Greenheys again		1.33
Cavendish-street, 5,000 grs. used		3.010

ORGANIC MATTER.

Greenheys	.56
Cavendish-street, June	1.960
Park-street	4.200
Greenheys fields	2.799
Moss-side	1.45

CHLORINE IN A GALLON.

Greenheys	.47712
Cavendish-street, June 8th, 1851	.3976
" " 9th	.5300
Moss-side	.896

SULPHURIC ACID IN A GALLON.

Greenheys	0.3840
Cavendish-street	1.0752
"	1.0752
"	.5972
Greenheys fields	.4480
Park-street-outskirts	.5376
" "	.5376
" "	.6740
Timperley	2.2400
Moss-side fields	.8960

Note.—There is an unaccountable quantity at Timperley. This requires explanation. The wind was from the west, and violent. Did it receive its impurity from an upper current?

The quantity of acid was determined by comparing prepared solutions. I doubt if it is very accurate with baryta, and do not intend to use it again.

LIST OF BOOKS

PRESENTED TO THIS SOCIETY FROM DECEMBER 10TH, 1851, TO NOVEMBER 2ND, 1852.

Donors.	Titles of Books.
LITERARY & PHILOSOPHICAL SOCIETY OF LIVERPOOL.	Proceedings of the Literary and Philosophical Society of Liverpool, Vol. VI.
SMITHSONIAN INSTITUTION, WASHINGTON.	Fourth and Fifth Annual Reports of the Board of Regents of the Smithsonian Institution.
" "	Report of the Smithsonian Institution on the history of the Discovery of Neptune, by BENJ. ABTHORP GOULD, jun.
" "	Smithsonian Reports—Notices of the Public Libraries in the United States, by CHARLES C. JEWETT.
" "	FORSTER and WHITNEY'S Report to Congress.
" "	Patent Office Report for America, 1848.
" "	Smithsonian Contributions to Knowledge, Vol. II.
" "	" " " Vol. III.
" "	" " " Vol. IV.
" "	First Appendix to the Third Volume of Smithsonian Contributions to Knowledge, "An Ephemeris to the Planet Venus for 1852," by SEARS C. WALKER.
" "	History of the Condition and Prospects of the Indian Tribes of the United States, by H. R. SCHOOLCROFT, LL.D. Illustrated by Captain EASTMAN, U.S.A. First Volume.
" "	Smithsonian Reports on the recent Improvements in the Chemical Arts, by BOOTH and MORFIT.
" "	Directions for Collecting Specimens of Natural History.
" "	Registry of Periodical Phenomena.
" "	List of Books published by the Smithsonian Institution.

Donors.	Titles of Books.
Smithsonian Institution, Washington.	List of Foreign Institutions with which the Smithsonian Institution is in correspondence.
" "	Abstract of the Seventh Census of the United States.
" "	American Zoological, Botanical, and Geological Bibliography, for the year 1851, by Charles Girard.
Sent through the Smithsonian Institution.	Report on Sugars and Hydrometers, by Professor R. S. Mc. Culloch. 1848.
" "	Report of the Commissioner of Patents for 1850. Part 1st—Mechanical Part 2nd—Agricultural
Superintendent of Weights and Measures.	Tables used with the Custom-house Hydrometers.
Surgeon-General of the United States.	Army Meteorological Observations for Twelve years, 1831-42.
" "	Second and Third Reports on Meteorology to the Navy Department, by Professor J. P. Espy. 1851.
Commissioner of Patents.	United States Patent Laws.
" "	Rules for obtaining Patents in the United States.
Commissioner of Indian Affairs.	History, Condition, and Prospects of the Indian Tribes of the United States, by H. R. Schoolcroft, LL.D. Illustrated by Captain Eastman. Vol. II.
The American Association for the Advancement of Science.	Proceedings of the American Association for the Advancement of Science; fourth meeting, 1850.
J. N. Nicollet.	Hydrographical Basin of the Upper Mississippi, from Astronomical Barometrical Surveys and Information, by J. N. Nicollet.
L'Observatoire Central de Russie.	Annales de L'Observatoire Physique Central de Russie, par A. T. Kupffer. Nos. 1, 2, and 3, 1848.
" "	Compte Rendu Annuel, par A. T. Kupffer. St. Petersbourg. 1850.
Mr. James Higgin.	Comptes Rendus, for 1850-51.
Museum of Practical Geology, London.	Introductory Lectures—by Professors Percy, W. W. Smyth, Ramsay, Forbes, Playfair, and Sir H. de la Beche.

Donors.	Titles of Books.
SCOTTISH SOCIETY OF ARTS.	Transactions of the Royal Society of Arts, Vol. III., Part 5.
INSTITUTE OF CIVIL ENGINEERS.	Proceedings of the Institute of Civil Engineers, up to 1st Part of, 1850-51; with List of the Members.
ROYAL SOCIETY OF EDINBURGH.	Proceedings of the Royal Society of Edinburgh, 1851-52.
" "	Transactions, Vol. XX., Part 3.
ROYAL SOCIETY.	Philosophical Transactions, Part 1, 1851.
" "	Proceedings of the Royal Society (continued)
M. EMANUEL LIAIS (the Author.)	L'Eclipse au 28 Juillet, 1851.
" "	Addition à un Memoire intitulè Theorie Mathematique des Oscillations du Barometre.
CAMBRIDGE LITERARY AND PHILOSOPHICAL SOCIETY.	Transactions of the Cambridge Literary and Philosophical Society, Vol. IX., Part 2, 1851.
MATTHIAS DUNN, Esq. (the Author)	Report of MATTHIAS DUNN, Esq., Inspector of Coal Mines, 1851.
JOS. DICKENSON, Esq.	Report of JOS. DICKENSON, Esq., Inspector of Coal Mines, 1851.
EDINBURGH ASTRONOMICAL SOCIETY.	Edinburgh Astronomical Observations, Vol. X., 1844, 1845, 1846-47.
SOCIETY OF ANTIQUARIES.	Proceedings of the Society of Antiquaries, 1849-52.
" "	Archæologia, Vol. XXXIII. and Vol. XXXIV.—2 Parts.
W. HOPKINS, Esq., Cambridge.	Address to the Geological Society by Professor HOPKINS, President, February, 1852.
ECOLE DES MINES.	Annales des Mines, to the 2nd Livr. of 1852.
PHYSIKALISCHE GESELLSCHAFFT, Berlin.	Fortschritte der Physik, 4th year, by KARSTEN.
PROFESSOR W. THOMSON, Glasgow, (the Author.)	Mechanical Theory of Electrolysis, by W. THOMSON.
" "	Theory of Magnetic Induction in Crystalline and Non-Crystalline Substances, by W. THOMSON.
" "	Mechanical Theory of Magnetism.
" "	Dynamical Theory of Heat, with Numerical Results deduced from Mr. JOULE'S Equivalent of a Thermal Unit, by W. THOMSON.

BEQUESTS.

A Silver Inkstand, which had been presented to Dr. DALTON by the Mechanics' Institution, bequeathed by the late PETER CLARE, F.R.A.S., Vice-President of this Society.

A Portrait of PETER CLARE, Esq., bequeathed by the late SAMUEL ELSWORTH COTTAM, F.R.A.S.

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SESSION 1852-53.

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AN

ALPHABETICAL LIST OF THE MEMBERS

OF THE

LITERARY AND PHILOSOPHICAL SOCIETY

OF MANCHESTER,

OCTOBER 19TH, 1852.

	Date of Election.
James Ainsworth	January 25th, 1805
Ralph F. Ainsworth, M.D.	April 30th, 1839
Thomas Ashton, M.D.	October 29th, 1824
Thomas Ashton, *Hyde*	August 11th, 1837
John Atkinson	January 27th, 1846
W. H. Ash	April 17th, 1849
Richard Parr Bamber	October 19th, 1821
Robert Barbour	January 23rd, 1824
Joseph Barratt	April 19th, 1842
John Frederic Bateman, M. Inst. C.E.	January 21st, 1840
Thomas Bazley	January 26th, 1847
William Bell	January 26th, 1847
James Bevan	January 23rd, 1844
Edward William Binney	January 25th, 1842
Alfred Binyon	January 26th, 1838
Richard Birley	April 18th, 1834
James Black, M.D., F.G.S.	April 30th, 1839
Henry Bernoulli Barlow	January 27th, 1852
John Blackwall, F.L.S.	January 26th, 1821
Henry Bowman	October 29th, 1839
Edward Brooke	April 30th, 1824
W. C. Brooks, M.A.	January 23rd, 1844

	Date of Election.
Henry Browne, M.B.	January 27th, 1846
Laurence Buchan	November 1st, 1810
John Burd	January 27th, 1846
Rev. R. Bassnett, M.A.	April 17th, 1849
Frederick Crace Calvert, M.R.A.T.	January 26th, 1847
John Young Caw	April 15th, 1841
David Chadwick	April 20th, 1852
Henry Charlewood	January 24th, 1832
Charles Clay, M.D.	April 15th, 1841
Charles Cleminshaw	April 29th, 1851
Rev. John Colston	October 29th, 1850
Thomas Cooke	April 12th, 1838
Samuel Crompton	April 29th, 1851
James Crossley	January 22nd, 1839
Joseph S. Crowther	January 25th, 1848
Charles Cumber	November 1st, 1833
Matthew Curtis	April 18th, 1843
John Benjamin Dancer	April 19th, 1842
Samuel Dukinfield Darbishire	Jannary 25th, 1822
Rev. John Davies, M.A.	January 21st, 1851
James Joseph Dean	November 15th, 1842
Thomas Dickson	January 27th, 1852
Joseph Cheeseborough Dyer	April 24th, 1818
Frederick Nathaniel Dyer	April 30th, 1850
The Right Hon. the Earl of Ellesmere, F.G.S.	April 15th, 1841
Thomas Fairbairn	April 30th, 1850
William Fairbairn, F.R.S., M. Inst. C.E., Inst. Nat. Paris. Corresp.	October 29th, 1824
W. A. Fairbairn	October 30th, 1849
Octavius Allen Ferris	January 26th, 1847
David Gibson Fleming	January 25th, 1842
William Fleming, M.D.	April 18th, 1828
Richard Flint	October 31st, 1818
Edward Frankland, Ph. D., F.C.S., Professor of Chemistry, Owen's College	April 29th, 1851
Robert Finlay, B.A., T.C.D., Professor of Mathematics, Manchester New College	October 21st, 1851
Rev. William Gaskell, M.A.	January 21st, 1840

	Date of Election.
Samuel Giles	April 20th, 1830
Thomas Glover	January 21st, 1831
John Goodman, M.D.	January 25th, 1842
John Gould	April 20th, 1847
John Graham	August 11th, 1837
Robert Hyde Greg, F.G.S.	January 24th, 1817
William Rathbone Greg	April 26th, 1833
Robert Philips Greg	October 30th, 1849
John Edgar Gregan	January 25th, 1848
John Clowes Grundy	January 25th, 1848
Robert Greaves	January 27th, 1852
Rev. Robert Halley, D.D.	April 29th, 1845
Richard Hampson	January 23rd, 1844
John Hawkshaw, F.G.S., M. Inst. C.E.	January 22nd, 1839
William Charles Henry, M.D., F.R.S.	October 31st, 1828
Sir Benjamin Heywood, Bart., F.R.S.	January 27th, 1815
James Heywood, M.P., F.R.S. & G.S.	April 26th, 1833
James Higgins	April 29th, 1845
Peter Higson	October 31st, 1848
John Hobson	January 22nd, 1839
Eaton Hodgkinson, F.R.S., M.R.I.A., F.G.S., &c.	January 21st, 1820
James Platt Holden	January 27th, 1846
Thomas Hopkins	January 18th, 1823
Henry Houldsworth	January 23rd, 1824
James Higgin	April 29th, 1851
Paul Moon James	January 27th, 1837
John Jesse, F.R.S., R.A.S., & L.S.	January 24th, 1823
Rev. Henry Halford Jones, F.R.A.S.	April 21st, 1846
Joseph Jordan	October 19th, 1821
James Prescott Joule, F.R.S., &c.	January 25th, 1842
Benjamin Joule, jun.	April 18th, 1848
William Joynson	January 27th, 1846
Richard Johnson	April 30th, 1850
Alexander Kay	October 30th, 1818
Samuel Kay	January 24th, 1843
John Kennedy	April 29th, 1803
John Lawson Kennedy	January 27th, 1852
Richard Lane	April 26th, 1822
William Langton	April 30th, 1830

	Date of Election.
John Rowson Lingard	January 26th, 1847
Thomas Littler	January 27th, 1825
John Lockett	January 25th, 1842
Joseph Lockett	October 29th, 1839
Benjamin Love	April 19th, 1842
Joseph Leese, jun.	April 30th, 1850
Edward Lund	April 30th, 1850
Isaac Waithman Long, F.R.A.S.	January 27th, 1852
James M'Connel	October 30th, 1829
William M'Connel	April 17th, 1838
Alexander Mc. Dougall	April 30th, 1844
John Macfarlane	January 24th, 1823
Edward William Makinson, M.A.	October 20th, 1846
The Right Rev. the Lord Bishop of Manchester, D.D., F.R.S., F.G.S.	April 17th, 1849
Robert Manners Mann	January 27th, 1846
James Meadows	April 30th, 1830
Thomas Mellor	January 25th, 1842
William Mellor	January 27th, 1837
John Moore, F.L.S.	January 27th, 1815
L. A. J. Mordacque	October 29th, 1830
David Morris	January 23rd, 1849
George Murray	January 27th, 1815
Alfred Neild	January 25th, 1848
William Neild	April 26th, 1822
John Ashton Nicholls, F.R.A.S.	January 21st, 1845
William Nicholson	January 26th, 1827
James Emanuel Nelson	January 27th, 1852
George Wareing Ormerod, M.A., F.G.S.	January 26th, 1841
Henry Mere Ormerod	April 30th, 1844
John Owen	April 30th, 1839
George Parr	April 30th, 1844
John Parry	April 26th, 1833
George Peel, M. Inst. C.E.	April 15th, 1841
Archibald Prentice	January 22nd, 1819
Joseph Atkinson Ransome, F.R.C.S.	April 29th, 1836
Thomas Ransome	January 26th, 1847
Rev. John Gooch Robberds	April 26th, 1811
Richard Roberts, M. Inst. C.E.	January 18th, 1823

	Date of Election.
Samuel Robinson	January 25th, 1822
Alan Royle	January 25th, 1842
Samuel Salt	April 18th, 1848
Michael Satterthwaite, M.D.	January 26th, 1847
Edward Schunck, Ph. D., F.R.S., &c.	January 25th, 1842
Salis Schwabe	April 20th, 1847
John Sharp	October 28th, 1824
John Shuttleworth	October 30th, 1835
Joseph Sidebotham	April 20th, 1852
George S. Fereday Smith, M.A., F.G.S.	January 26th, 1838
Robert Angus Smith, Ph. D., F.C.S.	April 29th, 1845
Edward Stephens, M.D.	January 24th, 1834
Ferdinand Sichel	April 29th, 1851
Peter Spence	April 29th, 1851
Archibald Sandeman, M.A., Professor of Mathematics, Owen's College	April 29th, 1851
Thomas Standring	January 27th, 1852
James Stephens	April 20th, 1847
Daniel Stone, jun.	January 23rd, 1849
Robert Stuart	January 21st, 1814
Rev. John James Tayler, B.A.	January 26th, 1821
David Thom	April 20th, 1852
John Thom	January 27th, 1840
James Aspinal Turner	April 29th, 1830
Thomas Turner, F.R.C.S.	April 19th, 1821
Absalom Watkin	January 24th, 1823
Joseph Whitworth	January 22nd, 1832
Matthew A. Eason Wilkinson, M.D.	January 26th, 1841
William James Wilson, F.R.C.S.	April 29th, 1814
Gilbert Winter	November 2nd, 1810
George Bancroft Withington	January 21st, 1851
William Rayner Wood	January 22nd, 1839
George Woodhead	April 21st, 1846
Edward Woods	April 30th, 1839
Robert Worthington, F.R.A.S.	April 28th, 1840
James Woolley	November 15th, 1842
William Crawford Williamson, F.R.S., &c., Professor of Natural History, Owen's College	April 29th, 1851
Joseph St. John Yates	January 26th, 1841
James Young	October 19th, 1847

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